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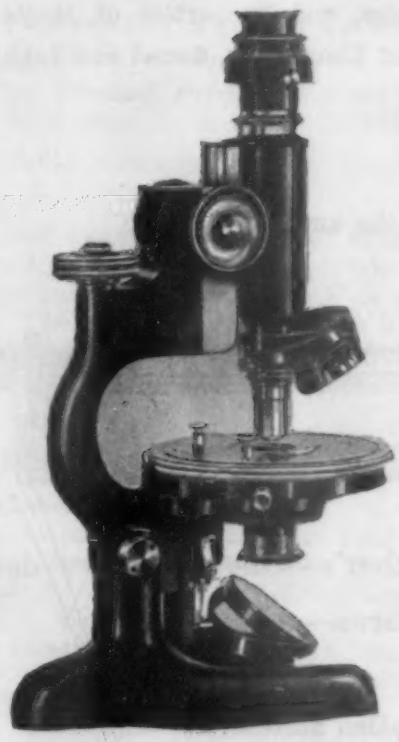

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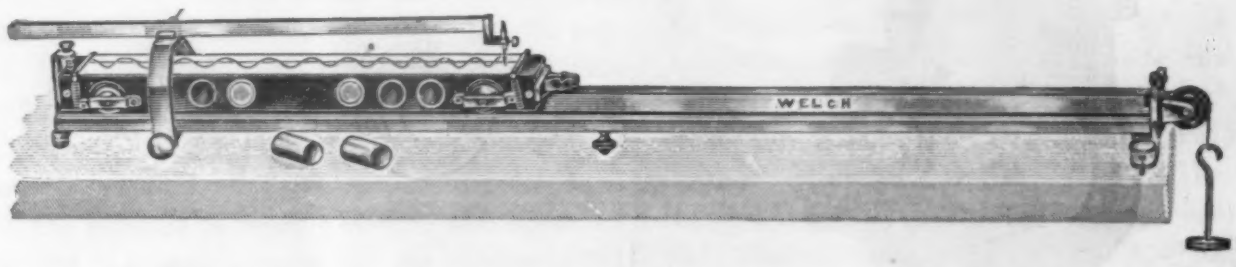

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SCIENCE

VOL. LXIX JANUARY 18, 1929 No. 1777

CONTENTS

The American Association for the Advancement of Science:
The Relation of Statistics to Modern Mathematical Research: PROFESSOR DUNHAM JACKSON 49

The Increased Efficiency of American Agriculture: PROFESSOR L. E. CALL 54

The World's Two Greatest Petrified Forests: PROFESSOR G. R. WIELAND 60

Samuel Bonsall Parish: PROFESSOR W. L. JEPSON 63

Scientific Events:
The International Congress of Tropical Medicine; The Engineers Memorial at Louvain; Storm Damage to the Experiment Stations in the West Indies and Florida; The Program of Research of the Corn-borer Conference; Program of the American Philosophical Society 63

Scientific Notes and News 66

University and Educational Notes 69

Discussion and Correspondence:
The Missing Link in Stellar Evolution: PROFESSOR C. D. PERRINE. *Resonance Radiometry:* DR. A. H. PFUND. *Hall Effect in Single Metal Crystal:* PROFESSOR P. I. WOLD. *Dissociation of Neutral Vaccine Virus-immune Serum Mixtures:* DRS. PERRIN H. LONG and PETER K. OLITSKY. *Prickly Pear Work:* DR. A. C. D. RIVETT 69

Reports:
The Influenza Epidemic 73

Scientific Apparatus and Laboratory Methods:
Mounting Amphibia by Paraffin Infiltration: DR. RALPH G. CLAUSEN 74

Special Articles:
The Growth of Hookworm Larvae on Pure Cultures of Bacteria: DR. OLIVER R. MCCOY. *The Excitation of Luminescence by the Agitation of Mercury in Glass and Transparent Fused Silica Tubes and Vessels:* W. L. LEMCKE. *The Inorganic Constituents of Milk:* NORMAN C. WRIGHT and JACOB PAPISH 74

Science News x

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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE RELATION OF STATISTICS TO MODERN MATHEMATICAL RESEARCH[1]

THE annual meeting of Section A, in conjunction with the other mathematical organizations, and in affiliation with the bodies devoted to progress in all departments of science, gives us occasion as mathematicians to pause and look about us, to be stirred by the proximity of the major activities of the rest of the scientific world, and to form a renewed estimate of our place in the general scheme of things. During most of the year we are occupied with our own problems, or in consultation with a colleague in a neighboring field about a particular aspect of some special investigation, the further implications of which he has time to explain only incompletely, and we imperfectly to understand. Occasionally it is well to reassemble the detached items which have engaged our attention from time to time, and to judge the broad tendencies of which they are significant.

We are constantly reminded that our affiliations are no longer so exclusively with physics and astronomy as was formerly the case. Not only chemistry, but also the biological and social sciences are taking us into their confidence, and welcoming us to the discussion of their projects and their difficulties. A former pupil of mine appears on the records of the graduate school as a candidate for the degree of Ph.D. with psychology as major subject, and a minor divided between mathematics and botany. One can imagine the derision with which such a combination would have been greeted a few years ago. His thesis is a statistical investigation of a psychological problem, in support of which he has taken courses in the mathematical theory of statistics and in biometry. The fact that derision among workers in different fields has been so largely replaced by respectful attention is one of the most wholesome features of the situation.

The diversion of a part of our energies into new channels does not mean that the problems of mathematical physics are any less challenging than before. Within our own recent memory the doctrine of relativity has constituted a major upheaval in the realm of pure mathematics as well as in physics. There has

[1] Address of the vice-president and chairman of Section A—Mathematics, American Association for the Advancement of Science, December, 1928.

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perhaps never been a time when current physical discussion was more prevailingly mathematical than in its present analysis of atomic structure. But changes in the mathematical basis of this discussion are so rapid that only those in the front line of investigation can hope to keep pace with them. Some one has said that anything printed on the subject of the quantum theory is *ipso facto* out of date. How much more is it true that by the time the ordinary mathematician has mastered any particular phase of the theory with anything like what he regards as finality, that phase has become a doubtful contender even for historical interest. In turning our attention to the newer applications of mathematical method, we are both responding to the needs of the sciences concerned and finding for ourselves a welcome outlet for some of the products that we are more readily able to supply.

It is not to be expected that we shall soon have the same power of prediction in the new fields that we have in the exact sciences, traditionally so called. The erection of a logical structure to any considerable elevation requires a firm foundation in the shape of an adequately comprehensive system of postulates, and vital phenomena are too complex to be accounted for by any manageable formulation. There is a constant danger of over-refinement bringing conclusions into discredit. A speaker before a local meeting a good many hundred miles from New York had gathered comparative statistics on the price of hogs and the number of students electing Latin in a certain group of colleges, or something of the sort, and reported "a coefficient of correlation of .3999, or very nearly four tenths." Just what important social consequences would have ensued if the correlation really had been as high as four tenths, instead of a little less, he omitted to say. The endeavor to describe human affairs in mathematical terms is an old one. Many essays in that direction have come to grief by attempting from the outset to accomplish the impossible. The present revolutionary extension of the domain of the applications of mathematics is due partly to the development of an appropriate technique, partly to social conditions which have made practicable the assembling of adequate statistical data, and partly to the acceptance of a working balance between aspiration and the possibility of achievement.

A necessary condition for the development of the classical dynamics was not only the creation of the mathematical tools, but also the isolation of the physical concepts which are susceptible of satisfactory mathematical treatment, and the recognition of the quantities which are fundamental in the controlling equations, such as acceleration, energy and the like. This was a long and temporarily uncertain process. The boy in your mechanics class who tells you that the velocity of a projectile in flight is one of the forces acting on it, is only repeating the gropings which the pioneers in the science must have gone through. Having been impressed at an uncritical age with the principle of the conservation of energy, I awoke to a painful realization that I did not know what energy meant, and the more I tried to find out, the more I was puzzled by the alleged importance of the conservation of so remote an abstraction, until it dawned on me in a flash of illumination that the importance of energy lay in the fact that it was the thing that was conserved.[2] The discovery of the existence of such a unifying permanence by the creators of the science was one of the things that made mathematical physics possible.

It is not apparent that there exists any small group of variables sufficient to characterize the phenomena of a living organism. A physical body is more or less homogeneous, or can be so considered for purposes of argument. With an organism this is not the case. Statistical prediction deals with organisms in the mass, while our vital human concerns are with organisms as individuals; and the individual has a complexity of parts, which demand separate consideration with regard to their several functions. There is no prospect, humanly speaking, that we shall ever have methods for the practical handling of complicated differential equations in several dozen or several million variables. In the controversy between mechanist and vitalist, between behaviorist and subjectivist, the part of the mathematician must occasionally be the inglorious one of counseling moderation. He is too familiar with the limitations of calculation to see in them, or in the present limitations of any science, need for invoking supernatural intervention. But when he considers that an exhaustive discussion of the dynamics of a single atom of helium transcends our powers for the time being, and lifts his eyes from an atom of helium successively to an atom of carbon, a molecule of sugar, a molecule of protoplasmic substance, a living cell, a toadstool, a tree, a guinea pig and a professor of mathematics, he does not look for any early reduction of the laws of life to a system of differential equations which he can integrate.

Nevertheless, the extension of the scope of quantitative methods through the medium of statistical analysis is one of the most significant things going on in the scientific world at the present time. It is noteworthy that it has gone so far with comparatively little attention from mathematicians, and that statisti-

[2] It may be noted that the substance of this passage was written before the appearance of Professor Swann's article in SCIENCE for November 2, 1928; *cf.* especially page 418.

cians have independently reconstructed so much that a simple adaptation of existing mathematics would have given them outright. Even now there is a prevalent idea that statistics, if properly regarded as a branch of mathematics at all, is a remote and highly specialized one. It is my purpose here to show how some of the fundamental notions of statistics fit directly into the frame of modern mathematical research. In doing this I shall not have anything to offer that is essentially new. I shall only be repeating things that are already well known in substance, in a form and with an emphasis appropriate to the occasion.

Professor E. B. Van Vleck (in volume 39 of SCIENCE) has called attention to the dominant influence of the study of Fourier series on the progress of mathematics during the past hundred years, as far as it relates to the theory of functions of real variables. The theory of the Fourier series itself is still a living issue, and within the memory of most of us has produced in the work of Fejér one of the most beautifully simple and satisfying theorems of modern analysis. Investigation of other analogous series of mathematical physics, such as those of Legendre and Bessel, is actively in progress at a less advanced stage. The broader generalizations relating to the series associated with differential systems and integral equations have occupied a large part of the attention of European and American mathematicians in our time. And the still wider horizon of the general function concept, which we owe in large measure to these researches, extends itself from year to year.

It is interesting, as an aside, to recall a passage from the early pages of Les Misérables, describing the state of French civilization in the year 1817: "Il y avait a l'académie des sciences un Fourier célèbre que la postérité a oublié et dans je ne sais quel grenier un Fourier obscur dont l'avenir se souviendra." One wonders whether the author, if he could return to the scene, would be mildly surprised by the verdict of subsequent history, or would dismiss the actual facts as irrelevant and serenely reiterate his original assertion.[3]

Whatever scale of values the novelist might set up for mankind generally, a systematic account of the properties of Fourier series and their successive implications can be made to embrace a very large domain of our technical concerns as mathematicians. And in this domain, by intimate association and abstract identity, are contained the leading ideas of mathematical statistics.

Nothing in the theory of Fourier series is more striking than the least-square property. The partial sum of the series for a given function $f(x)$, through terms of the nth order, is a linear combination of the functions $1, \cos x, \cdots, \cos nx, \sin x, \cdots, \sin nx$. It is characterized among all such linear combinations as the one which gives the best approximation to $f(x)$, in the peculiar sense that the integral of the square of the error, extended over a period, is a minimum. This relation to the classical method of least squares for the adjustment of observations, appearing at first perhaps as a mere superficial analogy, gradually assumes a fundamental significance.

It is speedily recognized that the least-square property has a wide range of generality. Its proof in the case of the Fourier series depends clearly and directly on the orthogonality of the sines and cosines that make up the series, the fact that the integral of the product of any two of them over a period is zero, the same fact which leads to the familiar determination of the coefficients. It can therefore be extended immediately to other series in which the coefficients are similarly determined. Not only the Legendre series, but also the series of orthogonal functions obtained from linear differential equations with boundary conditions or from integral equations, in fact all series of orthogonal functions generally, have the property that their partial sums give a closest approximation in the sense of the method of least squares.

The part played by the relations of orthogonality is so conspicuous that it tends to mask a certain further significance of the results. Renewed consideration shows that these relations are a convenience in calculation, rather than a condition essential to the treatment of the problem. An arbitrary linear combination of the first $n+1$ Legendre polynomials, for example, is nothing more nor less than an arbitrary polynomial of the nth degree. The partial sum of the Legendre series for a given $f(x)$ is merely the polynomial of corresponding degree which gives the closest possible approximation to $f(x)$ according to the least-square criterion. It can be defined and studied as such, without any reference to the special properties of the Legendre polynomials at all. A similar procedure is possible in the case of approximation by linear combinations of any given linearly independent functions. The existence of the Legendre polynomials, fulfilling the condition of orthogonality, does not depend on any peculiarity of the functions $1, x, x^2, \cdots$, of which they are built up. If any set of linearly independent functions is given, it is possible to construct a sequence of linear combinations of them which shall be orthogonal to each other. The construction of such a set of orthogonal functions, familiar now in connection with the theory of integral equations, is commonly spoken of as "Schmidt's process," with reference to the thesis of Erhard

[3] It may be worth recording in this connection that the birthplace of the sociologist Fourier and that of Victor Hugo are a few doors apart in the same street of the same French provincial town.

Schmidt, a classic among original memoirs in mathematical research for clearness and elegance of presentation, though Schmidt himself ascribes the essence of the construction to Gram, and one suspects that Gauss would have smiled complacently at a suggestion that the method in Gram's hands was radically novel. The actual carrying out of the process, found thus to be always possible, is for many purposes unnecessary.

It is at this point that one of the far-reaching generalizations of modern analysis becomes pertinent. Reference has already been made to the emergence of the function concept from the study of the types of series that have been under discussion. In the "functional analysis" or "general analysis" of recent decades, crystallizing ideas which had long been current as exemplified in particular cases, not only the manner of dependence of one variable on another is arbitrary, but also the range of values taken on by the independent variable. Instead of ranging over an interval, it may in particular be restricted to a finite number of values. A set of numbers $x_1, x_2, \cdots, x_n$ may be regarded as a function x_k of the index k, which takes on the values 1, 2, $\cdots$, n. Many of the relations which are fundamental in the theory of approximation carry over to this type of functional dependence without essential change. The problem of a least-square approximation of a given "function" by a linear combination of other given "functions" becomes the problem of determining a regression formula; and the mathematical processes of statistics begin to take their place in the general outline. The practical cases are excessively simple, to be sure, from the point of view of the general theory, the number of "functions" in terms of which the approximation is to be expressed being usually one, less frequently two, and always small, but even so the characteristic features of the problem are retained to such an extent that the identification is a genuinely significant one. Incidentally, the equations for determining the coefficients, when formulated in general algebraic terms, become the normal equations of the classical method for the approximate solution of a system of linear equations by least squares. Working out the theory of the regression formulas in systematic fashion, one obtains the solution of the older problem at the same time, without extra charge. And while the use of the calculus to obtain a proof of an elementary theorem in algebra may seem *a priori* like a roundabout procedure, it is actually true that for one who is already familiar with the calculus the formulas of integration are often simpler, clearer and more suggestive than those of summation, whether because of a more convenient notation or for a deeper reason, and a proof is often found most easily by thinking first in terms of integrals, and then translating into algebraic notation.

Familiarity with current mathematical notions presently throws light on the formulas of statistics from another angle. For the purpose of the method of least squares, the measure of the discrepancy between a set of numbers $x_1, x_2, \cdots, x_n$ and another set $y_1, y_2, \cdots, y_n$ is the quantity

$$(y_1-x_1)^2+(y_2-x_2)^2+\cdots+(y_n-x_n)^2.$$

It is a matter of course then to regard $(x_1, x_2, \cdots, x_n)$ and $(y_1, y_2, \cdots, y_n)$ as the coordinates of two points in n-dimensional space, and $\Sigma(y_k-x_k)^2$ as the square of the distance between them. This does not mean that the mathematician pretends to be physically cognizant of a space in which he can put his right shoe on his left foot, except by an exercise of professorial absent-mindedness. It means only that facts in the geometry of two or three dimensions often correspond to algebraic relations for which the restriction to two or three variables is irrelevant. While it is possible to build up a system of n-dimensional geometry on the basis of postulates, in Euclidean fashion, and while there are mathematicians who have trained themselves to think in terms of such postulates, the language of the geometry of higher dimensions is for most of us just a means of stimulating the imagination to a clearer insight into the structure of algebraic formulas. The notion of distance having received its algebraic expression, the next step is to define the measure of an angle, and this also is effected without difficulty. If the points $(x_1, \cdots, x_n)$ and $(y_1, \cdots, y_n)$ are denoted by P and Q, and if the origin is O, the cosine of the angle POQ is

$$\frac{\Sigma x_k y_k}{\sqrt{(\Sigma x_k^2)(\Sigma y_k^2)}}.$$

But this is just the formula for the coefficient of correlation between the variables (x) and (y). The term coefficient of correlation, to be sure, is applicable only if the x's and the y's are measured as deviations from their respective means, so that $\Sigma x_k = \Sigma y_k = 0$; but the algebraic identities underlying the theory are wholly independent of this restriction. If there are three variables $(x_1, \cdots, x_n)$, $(y_1, \cdots, y_n)$, and $(z_1, \cdots, z_n)$, represented by three points P, Q, R, the various coefficients of correlation measure the trihedral angle O-PQR, or the corresponding spherical triangle. The coefficient of partial correlation between (x) and (y) when (z) is "held fast," is the cosine of the dihedral angle between the planes POR and QOR, and the coefficient of double correlation between the variable (x) and the pair of variables (y), (z) is the cosine of the angle between the line OP and the plane QOR

If a critic demands logic to supplement analogy, there is no difficulty in putting the correspondences in such form that geometrical reasoning in the three-dimensional space of experience applies with cogent force. When more than three statistical variables are involved, the geometrical interpretation demands a plurality of dimensions in earnest, but even then geometrical analogy is genuinely helpful. While the fact that coefficients of correlation can be regarded as cosines has been recognized for some time, stress has usually been laid on a comparatively elaborate setting up of the correspondence for the special case of normal correlation, and the fundamental directness and simplicity of the more general interpretation has been largely disregarded.

Some one may have been disposed to object from the beginning that too much emphasis has been placed on the criterion of least squares as a measure of approximation. It may be argued, for example, that the method of moments is often preferable to that of least squares. A preliminary answer is that for the straightforward fitting of a polynomial curve the method of least squares and the method of moments give identical results. This is because the polynomial is made up of the same powers of the independent variable which enter into the definition of the moments. In other cases, to be sure, the two methods will in general work out differently; and still other methods may come into consideration. But to one who has pondered on the geometrical analogies set forth above, it seems that as long as a straight line is the shortest distance between two points, the least-square criterion is likely to retain a fundamental importance, however often it may happen that one or another of a variety of different measures offers an advantage in particular circumstances. In traveling from New York to Chicago, for example, it would be highly inexpedient to attempt to follow a straight line, or even a geodesic on the earth's surface, but one realizes nevertheless that the shortest path from one point to another has a more universal significance than the topography of the Hudson River or the Alleghany Mountains.

Another contention that may be advanced is that the coefficient of correlation is applicable only when the underlying dependence of one variable on the other is linear, and that uncertainty on this point invalidates any general assertion with regard to it. To this the mathematician will reply that it is not the definition of the correlation coefficient that is uncertain when there is doubt as to linearity of regression, and in default when the regression is non-linear, but its adequacy as a measure of the relationship in question. The algebraic consequences of the definition have all the precision and finality of any group of propositions in mathematics, and have merely to share with other abstract propositions the limitation that in a practical issue they may be occasionally beside the point. Incidentally it is to be noted that resort to a correlation ratio does not necessarily imply abandonment of the concept of correlation coefficient; for example, a correlation ratio based on the representation of y by a quadratic function of x is the same thing as the coefficient of double correlation of y on the pair of variables x and x^2.

The importance of the geometrical analogies is not limited to the statistical applications. Formulated with integrals in place of sums, and extended to an enumerable infinity of dimensions, they constitute the elements of the geometry of function space, a fascinating subject which is now under active investigation, and still at so early a stage of development that its ultimate scope is impossible to foresee. If the geometry of statistical measures and the geometry of function space had not received attention independently, either would inevitably have suggested the other, so compelling is the identity of their fundamental concepts.

Without going far afield, one finds the abstract theory of approximation and the theory of statistics merging along another frontier. The theory of the least-square approximation of a given function may be extended by the introduction of a weight function in the integral to be minimized, an extension suggested in the first instance no doubt by the weighting of data in practical problems of the adjustment of observations. Instead of integrating the square of the error directly, one multiplies it first by a given non-negative function of the independent variable, and seeks to minimize the integral of the product. This introduction of a weight function is both a unifying and a generalizing principle. The Legendre series, for example, can be obtained as a special case of trigonometric approximation, by the use of a suitable weight function and a simple change of variable. Apart from particular cases, the arbitrariness of the weights naturally opens up a wide range of generalization. After problems of approximation over a finite interval have been studied in this light, it is natural to proceed to the consideration of an infinite interval, with a weight function chosen so as to make the improper integrals convergent. And one of the most obvious weight functions in this connection leads directly to the Tchebychef-Hermite-Gram-Charlier series which is of importance in the analysis of frequency distributions.

The above outline is of course only illustrative. Apart from the method of least squares, problems of curve fitting and mechanical quadrature are perennially timely, both on the theoretical and on the prac-

tical side, and constitute an important bond between mathematical science and its applications. The alternative geometrical interpretation of coefficients of correlation for the special case of normal correlation, already referred to, involves an interesting application of the theory of quadratic forms. And the whole theory of approximation represents only a part, though in its widest scope a not inconsiderable part, of modern mathematics. Many other topics could be named as of common interest to students of mathematics and of statistics. There will inevitably be a shifting of emphasis as time goes on. It appears likely that the further development of the theory of probability in the next few decades may turn out to be a major chapter in the history of science. And if this prediction is to be verified, one may further surmise that its realization will demand the profoundest insight of the professional mathematician, and will result in an unprecedented extension of exact knowledge of the material world and of the workings of human society.

Dunham Jackson
University of Minnesota

THE INCREASED EFFICIENCY OF AMERICAN AGRICULTURE[1]

Food is the first and most urgent requirement of life. How to provide an adequate supply has been in the past the fundamental problem of mankind. From the dawn of history to our present highly developed western civilization, the food problem in one aspect or another has demanded public recognition. Ancient civilization developed only under conditions favorable for the production of food. Even so, a major portion of the population was engaged in its production. Only a few had leisure to devote to other occupations. Ancient civilization always declined when the production or the securing of food became difficult.

The food problem in one form or another has been to the fore in our own country from the first starvation winter of our Pilgrim Fathers to the present time, when the economic status of the food producer is one of our most urgent national problems. During this period there has taken place a fundamental change in the position which food supply occupies in the consciousness of the nation. In colonial times, nearly the entire attention of the population was devoted to food production. More than 95 per cent. of all producers were farmers. The entire family worked on the land. And yet there was produced scarcely more than enough to feed and clothe the people. The per capita exports in relation to those engaged in farming were far less than they are to-day.

Beginning with a condition when almost the entire population was rural and when the entire family worked on the farm, the efficiency of American agriculture has increased gradually until to-day less than one third of our population is rural, women and small children no longer work in the field, the length of the working day on the farm has been greatly reduced, exports of food and clothing products have increased, and the problem of how to avoid the production of a surplus of agricultural products resulting in the lowering of the economic status of the producer is one of our urgent national problems.

The rapidity with which the proportion of rural to urban population has declined is strikingly shown by the census reports. Thus in 1790 rural people (those who live on farms or in towns of 2,500 or less) made up 96 per cent. of the total population; in 1880, 71 per cent.; in 1890, 65 per cent.; in 1900, 60 per cent.; in 1910, 50 per cent.; and in 1920, 48 per cent.[2] The U. S. Department of Agriculture has estimated that on January 1, 1927, only 27,892,000 persons out of a total population of about 119,000,000, or less than 24 per cent., were actually living on farms. In other words, one family living in the country produces the raw material for food and clothing for three families living in towns and cities. In addition the exportable surplus of agricultural products has increased greatly. Thus with the exception of the period of the World War a larger volume of agricultural products was exported in the five-year period 1921–25 than for any similar period in the history of our country.[3]

At no time has agricultural progress as measured by production per man been more rapid than within the past few years. Dr. O. E. Baker, agricultural economist of the U. S. Department of Agriculture, in an address before the joint session of the Farm Economics Association and the Rural Section of the American Sociological Society in 1927 said:

> Agricultural production as a whole was over 14 per cent. greater in the period 1922–26 than in the period 1917–21, whereas population increased less than 9 per cent. between the midyears of these two five-year periods; in other words, the increase in agricultural production was over 50 per cent. greater than the increase in population.
>
> More surprising than this rapid increase in production and the resultant surplus, however, is the fact that this

[1] Address of the vice-president and chairman of Section O—Agriculture, American Association for the Advancement of Science, New York, N. Y., December 28, 1928. Contribution No. 41, Office of Director, Agricultural Experiment Station of Kansas.

[2] Census Monograph VI, Farm Population of United States for 1920.

[3] Statistical Abstract of the United States, 1926, p. 470.

condition has developed despite a decreased or at least a stationary acreage of crop land. The census of 1925 shows a decrease of about 13,000,000 acres in the area of crops harvested between 1919 and 1924, the first decrease shown by any census in our national history, while the average of estimates of the Division of Crop and Live Stock Estimates (U. S. Department of Agriculture) for the five-year period 1917–21, as compared with 1922 to 1926, indicates a decrease of 1,000,000 acres.

This increase in agricultural production that has taken place gradually through several generations but which has been accelerated since the close of the World War, is a measure of the increased efficiency which has taken place in American agriculture and which, it seems to me, is the result in a large measure of the application of science to American farming, and of industrial education to American farm life.

The application of science to farming has found expression in many ways. It has expressed itself in exploration, bringing to this country many new varieties of crop plants which have made possible a profitable agriculture in regions considered to be poorly adapted to agricultural purposes. It has expressed itself in the application of mechanical power to farm work, and it has further expressed itself in the protection and improvement of both plants and animals, which have prevented loss, eliminated waste and led to more efficient production.

The fruits of scientific discovery and invention could not have been applied to American agriculture—in fact it is doubtful whether much progress in scientific discovery and invention would have been made—if at the same time the American agricultural producers had not received an education that enabled them to take intelligent advantage of the discoveries and inventions as they were made. One discovery or invention frequently called attention to the need for others and thus served as a stimulus for further improvement. In fact, because of the high average intelligence and education of the American agricultural producing classes, discoveries and inventions for the facilitation of agricultural production have been made in many instances by the farmers themselves.

Let us now consider for a few minutes how each of these factors, namely, (1) the discovery and introduction of new crop plants, (2) the aid of mechanical invention and power, (3) the application of science to the production, improvement and protection of plants and animals and (4) the education of the American farmer and his family, has contributed to the present efficiency of American agriculture.

Introduction of Crop Plants

Our country was settled for the most part by people who emigrated from northwestern Europe. They found in New England and on the Atlantic coast agricultural conditions in general similar to those of their native land. The crops which they had grown at home and the agricultural practices which had been followed were successful in the new world. As the settlements in the new world developed and the pioneers pushed westward across the Appalachian mountains into Ohio, Michigan, Indiana and Illinois, they found conditions still so similar to the more fertile parts of northwestern Europe that the varieties of crop plants which had been brought by the colonists from western Europe and the agricultural practices of the old world modified to meet American conditions gave satisfactory results. There was no need as yet for distinctly different kinds and varieties of crop plants, or for a distinctly American type of agriculture.

When, however, they pushed still farther westward and attempted to settle the drier territory of the Great Plains, an area which had been described by explorers and historians as the Great American Desert, the old world crops were found to be decidedly unadapted and the old world methods unsuccessful. Before this area could become one of the leading grain-producing regions of the world, it was necessary to introduce crops unknown to the western European or the American colonial farmer and to develop a type of extensive agriculture based upon the maximum output of crop per man, a distinctly American contribution.

It would be difficult to overestimate the value of the immigrant crop plants in the development of this territory. They have come from every continent that contains large areas having natural conditions similar to those in the Great Plains. These crops have come partly as a result of emigration of settlers from these countries. But they have been introduced chiefly as a result of the far-sighted policy of the nation in establishing through the federal Department of Agriculture and the state agricultural experiment stations a policy of exploration for the discovery and introduction of new kinds and varieties of crop plants. This policy has included also the establishment of a system of field experiment stations where new introductions may be tested and, when proved of value, distributed through the territory to which they are adapted.

One of the earliest and most valuable introductions from the standpoint of acreage and aggregate value is hard red winter wheat from Russia. This valuable plant immigrant was first brought to this country by Mennonite farmers who emigrated to Kansas in 1873. Additional importations have been made since by the U. S. Department of Agriculture, mills, individual farmers and other agencies. These imported strains have been further improved by scientific plant breed-

ing by the U. S. Department of Agriculture and several of the state agricultural experiment stations as well as by a few interested progressive farmers. More than 12,000,000 acres of this type of wheat are now sown annually in the three states of Kansas, Nebraska and Oklahoma. A very large acreage is also grown in Texas, Colorado, Illinois and Montana. More than 50 per cent. of the total production of winter wheat in America is of this type. The substitution of this kind of wheat for spring wheat and soft red winter wheat, the only kinds available before the introduction of the Crimean type, has made wheat growing dependable where it was undependable before, and has extended wheat growing into parts of the United States entirely unadapted to less hardy varieties.

Farther north in the spring wheat belt, the introduction of durum wheat by the U. S. Department of Agriculture and of Marquis wheat from Canada has made possible a successful wheat industry in this territory. These introduced varieties have been further improved through plant breeding by workers in the U. S. Department of Agriculture, the Canada Department of Agriculture and the agricultural experiment stations in the northern Great Plains states.

Another large group of plants which deserve special mention because of the contribution they have made to the southern Great Plains region is the sorghums. This group contains numerous varieties used for many purposes. Some are grown chiefly for forage, others for grain, others for sirup and still others for broom making. While the introduction of the sorghums dates back in this country more than two centuries, those varieties which have been of greatest agricultural value have been introduced within the past fifty or sixty years. Several of the best ones have been produced in this country within the past twenty-five years by selection and breeding of sorghums introduced by the U. S. Department of Agriculture. They have come from places in Asia and Africa where natural conditions are essentially the same as those in the sorghum-growing regions here, that is, where summer temperatures are high and where periods of drought are of frequent occurrence. This crop, which is now successfully grown on millions of acres in Kansas, Oklahoma and Texas, and less extensively grown in New Mexico, Arizona and California, is making an important contribution to the development of the agriculture of these states.

One of the urgent needs of the early settlers of the Great Plains was for a leguminous forage crop that would take the place of red clover in the agriculture with which they were familiar. Red clover which had been introduced from western Europe and which had proved satisfactory in the east central and Atlantic coast states failed completely in all but the more humid sections of the Great Plains. The need for a leguminous forage crop was largely met by the introduction of two plant immigrants, alfalfa and sweet clover. The former is one of the oldest forage crops. It has been cultivated for centuries in Asia and southern Europe, and was introduced a number of times in the Atlantic coast states without success. It reached the farmers of the west by the way of California, where it had been introduced as early as 1854 from the west coast of South America. It was quickly recognized as a valuable crop for this region since it had the ability to withstand the extremes of both heat and cold and yet was capable of producing large yields of highly nutritious hay under favorable conditions. The crop promptly received the endorsement of the U. S. Department of Agriculture, the state agricultural colleges and the state departments of agriculture. The publicity which the crop received brought it rapidly to the attention of progressive farmers, by whom it was quickly accepted. It is now grown on nearly 2,500,000 acres in Kansas, Nebraska and Oklahoma, and on large areas under irrigation throughout the western half of the United States. It has filled an urgent need in the live-stock industry of this territory and has contributed much to an efficient agriculture for the central and western United States.

Sweet clover has become a valuable supplementary crop to alfalfa. It was brought to this country more than two centuries ago but for many years it was regarded as a dangerous weed. It is only within the past forty years that it has been recognized as one of the most valuable pasture and soil-improving crops. Sweet clover is now grown on many thousands of acres and within the past few years is even replacing red clover to some extent in rotations in the corn belt.

These are but a few of the new crops and crop plant varieties that have come to this country as immigrants. Many more valuable ones could be mentioned, but this number will suffice to illustrate the point that I wish to make, namely, that introduced crop plants have contributed in an essential way to the development of one of our most important agricultural regions, especially important because it is capable of being farmed in an extensive manner. It is in this region, perhaps as nowhere else in the United States that the American type of extensive farming with a maximum output per man has been developed. It has been this type of farming that has made possible the present high state of agricultural production in the United States. Thus plant immigrants have contributed materially to the increased efficiency of modern American agriculture.

THE CONTRIBUTION OF MECHANICAL POWER AND INVENTION

While the development of a highly efficient American agriculture has been dependent in part upon the introduction and production of adapted varieties of crop plants, it has also been dependent upon the development of efficient machinery with which to grow and harvest these crops and upon an economical source of power to operate the machinery. Three types of power have been and are still utilized in American agriculture, namely, human, animal and mechanical.

Human power has been important in agriculture throughout the ages. Until less than one hundred years ago it was the chief source of power. While agriculture depended for power primarily upon human energy little progress could be expected. Such power is inefficient and expensive. It is impossible for a human being to develop much energy through a long sustained period of work. When used as a motor, it has been estimated that a man will not develop more than one sixth to one tenth of a horse power of energy. He is, therefore, capable of doing only a very limited amount of work. Furthermore, the human being requires a high grade of food for sustenance. When human labor was the chief source of power it required almost the entire time of those engaged in the industry to produce the food that they consumed. Hence it was necessary for practically the entire population to devote its energy to food production. This condition prevailed in 1790, when 96 per cent. of our entire population was rural.

Late in the eighteenth and early in the nineteenth century marked changes in agricultural methods were brought about. The plow was improved. Simple tillage tools were perfected, and it was not long until the first harvesting machines were invented. Such implements could not be operated efficiently by human power; they were built for operation by animal power. It was not, however, until after the middle of the last century that horse-drawn harvesting implements fully replaced hand implements and the "machine age" in agriculture really began.

The use of the horse increased the power under the control of man from six to ten times for each animal employed. A man with a two-horse team and a simple machine was capable of doing twelve to twenty times as much work as he could do by hand. Teams of from four to six animals are now common units on the large farms of central United States, and as many as sixteen to twenty animals are sometimes used as a unit. The use of animals, increasing as it did the power available for the individual worker, greatly increased the area of land that he could handle. Thus it made possible the production of crops on large areas with a limited amount of human labor and marked the beginning of extensive agriculture.

The transition from animal power to mechanical power began with the introduction of the internal combustion engine shortly before the close of the last century. It was not, however, until the last decade that such power was used extensively in agriculture. The tractor, the combine harvester-thresher, and the truck, all driven by internal combustion engines, have now become thoroughly established farm machines. The rapidity with which they have been accepted is evidenced by the change that has taken place in such agricultural states as Kansas where the number of tractors increased from 5,400 in 1918 to over 50,000 in 1928 and the number of combine harvester-threshers rose from fourteen in 1918 to a number estimated to be not less than 20,000 in 1928. This change is typical of that which has taken place in the principal agricultural regions of America. Thus, not only has more power been made available for agriculture, but there has been released for other uses fifteen to twenty million acres of crop land formerly required to feed the animals which have been replaced by mechanical power.

Seventy-five years ago, when most of the operations on the farm were performed by human labor or at most with the power unit consisting of two horses, and when the walking plow, the spike tooth harrow, the scythe and the cradle were the most efficient farming tools, it was possible for the average farm laborer to care for only about twelve acres of crop land. Now with modern farm equipment he tills thirty-four acres of land. This represents an increased efficiency of nearly 300 per cent. In some of the more important agricultural states where most of the land is level and easily tilled and where large power units are operated and the latest labor-saving equipment is used the average area cultivated by each farm worker is one hundred acres. Moreover, on some individual farms in these states where conditions are especially favorable and where labor-saving equipment is more fully utilized as much as 300 acres is sometimes cultivated by each laborer. One laborer on such a farm to-day tills as much land as was cultivated by twenty-five average farmers seventy-five years ago.[4]

The value of modern harvesting machinery and mechanical power in increasing the efficiency of labor in harvesting the Kansas wheat crop has been well stated by Professor H. B. Walker, formerly head of the department of agricultural engineering at the Kansas State Agricultural College. He says:

> If it had been necessary to harvest the 1926 Kansas wheat crop by the method of one hundred years ago when

[4] U. S. Department of Agriculture Bulletin No. 1348.

the cradle and hand binding were in vogue, it would have required 775,000 harvest hands working twenty days to cut, bind and shock our last year's crop. If Kansas had been called upon to do this titanic task by these ancient methods it would have required all of the male population of the state between the ages of fifteen and sixty, and then in addition all of the women of the state between the ages of twenty and thirty-seven would have been necessary to complete a full harvest crew.

A century ago, an able-bodied man could cradle two acres of wheat in a day and it took two other men to bind and shock what he had cut. Or in other words it required three men to cut, bind and shock two acres of wheat in a day. With the present-day harvesting machines, that is, a 20-foot combine pulled by a modern tractor and with a farm motor truck for hauling grain, an equal number of men in a western Kansas wheat field can cut, thresh and deliver to market a distance of two miles forty-five acres of wheat in a day. This is fifteen times the acreage cut, bound and shocked by the three men of a century ago. Moreover, the work of the present-day harvest hand is less arduous and much more interesting.[5]

This increase in the efficiency of farm labor so well illustrated in the Kansas wheat harvest is typical of the change that has taken place in many other farm operations, although perhaps to a less marked degree. Mechanical power is being rapidly adapted to all kinds of farm operations including even farm chores and household work. Thus the gas engine and electric motor have been set to work not only in the field but in the farm yard—grinding feed, pumping water, milking cows and separating milk; and in the house washing clothes, sweeping floors, operating refrigerators, lighting buildings and doing many other tasks which have either not been done in the past or done less easily and conveniently by human or horse power. This transition has had a tremendous influence. It has not only increased the productive capacity of the farm worker but has likewise increased the standards of living of rural folks. It has made an important contribution to the efficiency of modern agriculture and to the enjoyment of country life.

THE CONTRIBUTION OF SCIENCE

While science has contributed in no small way to the efficiency of agriculture by the introduction of better crops and modern farm machinery, it has made its greatest contribution in the assistance it has afforded in the production, improvement and protection of domestic plants and animals. Agricultural progress has been coincident with increased scientific knowledge. The art of agriculture is old. It antedates written history. Progress, however, that resulted solely from the improvement in the art was meager and slow. The application of science to agriculture is new. All the sciences upon which agriculture is based are young. Chemistry is less than 150 years old, and modern chemistry in its application to agriculture is much younger. It has been only within the last fifty years that botany and zoology have contributed much to agriculture, while bacteriology in its application to agriculture is still younger. Without these sciences there is no basis for scientific agricultural progress. Without chemistry an understanding of the composition of feeds and the process of digestion is impossible. Without bacteriology and botany the diseases of plants and animals can not be comprehended. Without the application of biology and chemistry, the recent discoveries of food constituents necessary for the health of animals could not have been made.

The intensive application of science to the solution of live-stock feeding problems within the past fifteen years has resulted in a marvelously rapid increase in definite knowledge relating to an adequate diet for live stock. A great flood of new scientific evidence has shown the nutritive deficiencies of many of the rations that have been fed in the past. Many rations formerly considered adequate are now known to be deficient in mineral nutrients or vitamins or in the quality of the protein they contain. Thousands of young animals are now known to have been sacrificed simply because they or their mothers were not supplied with an adequate diet. The need of vitamins, the importance of sunlight as an aid to the assimilation and utilization of calcium by the young growing animals, and the importance in the diet of some of the less common elements such as iron, iodine, copper and manganese, are all recent discoveries made possible because of the application of science to the problems of nutrition. These new facts have revolutionized feeding methods and live-stock management. At no time in the history of the world has so much accurate information been available to the live-stock feeder and breeder as at the present time. This information has added greatly to the efficiency of live-stock production.

Another way in which science has been of service is in the assistance that it has given in the control of the pests of agriculture such as weeds, insects and plant and animal diseases. These pests have increased tremendously in number and virulence as agriculture has developed. Science has discovered practical means of preventing losses from most of them. Thus the discovery of anti-hog cholera serum and blackleg vaccine brought under control two of the most destructive animal diseases. It is estimated that before the discovery of blackleg vaccine the annual loss from this disease in single states frequently exceeded one and

[5] Report of Kansas State Board of Agriculture for the quarter ending March, 1927. "The Combine a Factor in Wheat Production," by H. B. Walker.

one half million dollars. Likewise the loss from hog cholera before preventive measures were discovered amounted to many millions of dollars. The control of these diseases by vaccination is now so successful that any appreciable loss from them can be attributed only to gross carelessness upon the part of producers. Without these preventive measures, losses to-day would probably be much greater than formerly, since these pests tend to increase in number and virulence as agriculture becomes more intensive.

The service of science in developing methods for the control of plant diseases has been equally valuable. Such plant diseases as the kernel smuts of wheat, oats, barley and sorghums can be effectively controlled by proper seed treatment. The formaldehyde vapor method of treating seed oats and the copper carbonate method of treating wheat and sorghum seed are not only simple and inexpensive but highly effective.

Science also has come to the aid of the farmer by developing methods for the control of insects. The poison bran mash developed for the control of grasshoppers has proved so effective when properly used that it would be safe to predict that there will never be another serious grasshopper plague in this country. Methods for effective and practical control have been developed for the Hessian fly, chinch bug, potato beetle, boll weevil, army worm, corn root louse, codling moth and numerous other field crop, orchard and garden insects. The saving which has resulted from the application of this knowledge amounts to millions of dollars annually.

Science has aided further by developing methods for the control of animal parasites. Detailed studies of the biology of parasitic worms, especially the parasitic worms of chicken and swine, have contributed information that has made possible the development of methods of flock and herd management which successfully control these pests.

The foregoing are but a few of the contributions of science to agriculture. Many others might be cited. These examples, however, will serve to illustrate the many ways in which scientific knowledge has aided in the solution of agricultural problems. The solution of these problems has contributed greatly to the efficient production of farm products both plant and animal. Thus, within the past ten years, an increase of only 4 per cent. in dairy cows and heifers in the United States has given a 20 per cent. increase in milk production. Approximately the same number of breeding hogs on farms has given a 25 per cent. increase in pork and lard slaughtered under federal inspection. Likewise during this period, crop products increased about 5 per cent., while the aggregate acreage of crops decreased slightly.[6]

THE INFLUENCE OF INDUSTRIAL EDUCATION

The remarkable increase in the efficiency of American agriculture, which has been most rapid within the past ten years, can not be attributed alone to scientific discovery, mechanical invention and crop plant introductions. These accomplishments, which have contributed so much to our present efficiency, would not have been made if the farm population of this country had not been composed largely of people of western European origin, capable of receiving instruction in science and willing to follow and be guided by the results of scientific research. It was the desire of American rural people for education and for definite information about farm problems that brought about the passage of the Land-Grant College Act in 1862, providing for the establishment of agricultural colleges, and the passage of succeeding acts making possible the establishment of the agricultural experiment stations and providing for agricultural extension education and vocational agricultural education. The creation of these educational and research agencies is merely the expression of the interest of the people in agricultural education and scientific research. But the creation of these facilities has made available facts and made possible the instruction that has led to the present efficient state of agricultural production.

The agricultural experiment stations and the U. S. Department of Agriculture have been in part responsible for the introduction and chiefly responsible for the improvement and dissemination of the new, introduced varieties of crop plants that have contributed so extensively to a successful agriculture in the central and western states. These agencies have also provided many of the scientists who have developed and applied scientific information which has made possible the solution of many of the perplexing problems of agriculture. They have also contributed liberally to the information necessary for the invention of modern farm machinery. Not the least of their contributions, however, has been their influence upon the older, established sciences of the country in calling attention to the need for the application of these sciences to the problems of the farm.

The desire of the rural folk for agricultural education, which expressed itself in the creation, first, of the agricultural college, then of the extension service,

[6] O. E. Baker, "Population, Food Supply and American Agriculture." U. S. D. A., Bur. of Agr. Econ. Address before the joint session of the Farm Economic Association and the Rural Section of the American Sociological Society, in Washington, December 29, 1927.

and finally resulted in the establishment of instruction in vocational agriculture in the high school, insured the success of these institutions. The agricultural college was slow in developing. Definite information relative to agriculture was meager when these institutions were started. This deficiency was to a large degree remedied by the establishment of the agricultural experiment stations, whose function it was to secure facts relating to agricultural problems. With these facts available, the colleges grew in importance and began to influence agricultural practice. It was, however, only after the creation of the extension service which carried the results of the scientific investigations of the agricultural experiment stations and the teachings of the agricultural colleges to the people that the influence of agricultural instruction upon the efficiency of production was markedly manifest.

The extent to which the extension service is influencing production practices was indicated in a recent report by C. W. Warburton, director of extension of the U. S. Department of Agriculture.[7]

This report states that during 1928, as a result of extension influence, over 4,100,000 instances were recorded of the adoption of improved practices on the farms and in the farm homes of the United States. Among the instances reported were 57,000 farmers who adopted improved practices in the production of alfalfa; nearly 30,000 who planted certified potato seed; 38,000 who treated seed wheat for smut; 418,000 who adopted improved dairy practices; and 424,000 who improved their marketing methods. These are but a few examples of the many ways in which adult education by the extension service contributed directly in a single season to a more efficient agriculture.

There should also be mentioned the educational work of the boys and girls through the 4-H clubs and vocational schools. Over 586,000 farm boys and girls were enrolled for instruction in 41,000 local 4-H clubs in 1926. These club members cultivated and owned 80,306 acres of field, truck and orchard crops; had 87,207 head of high quality live stock, and 1,329,200 standard bred fowls. Over 13,000 teams of club members were trained to give public demonstrations as a means of influencing more people to adopt improved agricultural practices. Formal agricultural instruction was also given to over 85,000 boys in the vocational agriculture classes in the high school. Thus in a single year these agencies trained an army of more than 600,000 young people in modern, advanced methods of farming. It is the influence of educational work of this character, started with the establishment of the Land-Grant Colleges in 1862, expanded as the vision of industrial education developed until it reached the magnitude described above, that has made possible the application of the results of scientific investigation and led to the present efficient state of agricultural production. In no other section of the world has agricultural education been made as easily available to the producing classes, and in no other country has agricultural production reached so high a state of efficiency.

The job of educating the agricultural producers of this country has just begun. The establishment of the first agricultural college is within the memory of men still living. The agricultural experiment stations are less than fifty years of age. Extension work in its modern conception was not started until 1914. Junior extension work has reached large numbers of boys and girls only within the past few years. Few who have received vocational agriculture instruction in the high schools have as yet become farm managers and operators. When all these agencies have had an opportunity to exert their full influence upon agricultural practices and rural life, a still further marked improvement in the efficiency of American agriculture can be confidently expected.

L. E. CALL
KANSAS AGRICULTURAL EXPERIMENT STATION

[7] Report of the director of the extension service, U. S. Department of Agriculture, for the fiscal year ending June 30, 1927.

THE WORLD'S TWO GREATEST PETRIFIED FORESTS

"LEAVING this island," said Sinbad—(for Scheherazade, it must be understood, took no notice of her husband's ill-mannered ejaculation)—"leaving this island, we came to another where the forests were of solid stone, and so hard that they shivered to pieces the finest tempered axes with which we attempted to cut them down." Thus, Edgar Allan Poe in the "Thousand and Second Tale"; and then he says in lucid footnotes, adding a strange literary touch, that an account at first discredited has since been corroborated, to the effect that "there is a completely petrified forest near the headwaters of the Chayenne, or Chienne river, which has its source in the Black Hills of the Rocky chain."

Told with the prescience of unapproachable genius there was in all the known world no other forest turned to stone, the equal of this of the "Chayenne." There were stems, crowns of fronds, flowers by the tens of thousands, ripened fruits, all stained in stone by nature, in faultless perfection. Those unimpeachable records had awaited throughout the ages the processes of erosion that should again bring them to

the surface of the earth. There was needed but the art of the lapidary to bring into view a life as remote as the light of the stars.

It is no exaggeration to say that within the limits of the area in the southern Black Hills "Rim" between the forks of the Cheyenne, now segregated as the "Cycad National Monument," there is a far richer representation of the petrified cycadeoids than has ever been indicated by field observation or discovery elsewhere. This has seemed to be the world's finest actually petrified forest. While in the like sense of completeness of record, in that rich and fadeless reality, one of the few ancient forests of the globe, fairly vying with the Cycad Monument forest, is surely the fossil Araucarian forest recently discovered in Patagonia.

The first word of this new and likewise "completely petrified forest" appears to have come through Dr. A. Windhausen, of the Argentine Geological Survey. When in the territory of Santa Cruz in the year 1919 he saw certain finely petrified cones in the hands of various persons. Reaching the general locality in the neighborhood of several volcanic outliers called the Cerro de Madre y Hija and Cerro Alto (S. L. 48°) some three years later, he then sent several of the cones to Dr. Gothan, of Berlin, described in 1925 as *"Araucaria Windhauseni."* But a rather more graphic account is given by Dr. Riggs, of the Field Museum of Natural History, Chicago, fairly a co-discoverer of the forest. While engaged in the Patagonian explorations of the years 1923–24, he also presently encountered the cones, so fascinating to the eye, literate or not. The first indication of the great forest came in the form of a cone brought out by the keeper of a "boliche" (country store) midway between Lakes Colue Huapi and Musters, said to come from "forty leagues southward." A month later, two similar cones were displayed in a roadhouse at Station Mazarado on the southern coast of the Gulf of St. George. These were from "twenty leagues to westward." Again the cones were seen at Station Jaramillo, at the crossing of the River Deseado.

As Dr. Riggs further relates:

> Employing the owner of these last specimens as a guide, after four days' travel by auto and search, we came upon the locality some fifteen miles westward and a little south of the volcanic peak, Cerro de Madre y Hija, and near that of Cerro Cuadrado. Here, three months after the first of the cones were seen, we found a considerable number of the fossil trees, some with stumps standing, others lying prone with broken branches and cones scattered about them, revealing a forest of fossil Araucaria, or Brazil pines, preserved on the site where it had grown. A large collection of these specimens was made.

Further picturing the nature of the forest floor, there are present a few finely petrified second year Araucarian seedling stems with their roots merely broken away during erosion—just such seedlings as are now seen freely growing in the Chilean pure stands of the Bio Bio, where there are in winter heavy falls of protecting snow.

Occurrence is in sandy volcanic ash. In accord, though not specifically proven, it is usual to believe that the broad leaf Araucaria type of foliage occurs in the older Mesozoic strata. In my own collections made in the Rhaetic of the Minas de Portrerillos, West Argentina, there are leaves of the size and cut of *Araucaria imbricata,* easily to be confused with those of the older Otozamitans, except for the much more distinct and closer venation of the latter.

With this splendid addition to the collections of the Field Museum, as successive interests have turned, especial attention is being given to ancient types of cones and flowers. Amongst other subjects, following the restoration of the *Cycadeoidea ingens* flower in glass after the manner of the "glass flowers," recently carried out by Dr. Dahlgren, study of the Araucarian series has been taken up, for both museum exhibition and comparative purposes. This elaboration, through the kindness of Professor Noé, of the University of Chicago, and the interest of the director, Dr. Davies, has been entrusted in part to me. It is thus one of the varied series of investigations resulting from five years of Field Museum activity in southern South America, recently noted in SCIENCE.

Sawing and polishing of a splendid group of nearly forty of the cones, large and small, from the great petrified forests of the Cerro de Cuadrado is already done, with also some thin sectioning; and the results are of such unexpected scientific value that the present preliminary account is given.

Most of the cones sectioned may be referred to the larger type studied by Gothan, *"Araucaria Windhauseni,"* the size and form closely recalling the present *Araucaria Cunninghamii.* Gothan's name appears, however, to be a synonym of *"Araucarites mirabilis"* of Spegazzini, who gave an account in the latter part of 1924 without geologic data. But with the advantage of such an extended series of cut cones, more perhaps than have ever been well cut in any single instance of study of an ancient petrified conifer, direct reference to the genus Araucaria seems slightly misleading—or to *Araucarites,* as the other alternative, inexact. Firstly, although Dr. Riggs is inclined to assign a later age to these cones, the opinion of Dr. Windhausen that they are of Triassic and probably mid-Triassic age is also that of a competent geologist, and in view of the features of the collections may prove more nearly correct. Secondly,

there is to be seen between the bract and ligular areas a deep sulcus. Whence a new generic name, *Proaraucaria,* is suggested for these larger cones. Also, as there is a tendency amongst them to run into two types, the one robust with a very large woody cylinder, and the other a more elongate type, two species may be present. If so, the elongate type might be singled out as *Proaraucaria elongata.* The name at least is one of convenience, emphasizing the presence of variation in the many specimens of the larger cone series.

Striking as are these larger cones of clear to jaspery and vari-colored quartz, beautiful as objects of museum display, and even distinct because of a certain primitiveness of feature, their evolutionary significance is but slight compared with that of a closely associated series of lesser cones of several types. These latter are fewer in number, although over a dozen have been cut and studied. Firstly, there is an approximately mature staminate form, certainly referable to the larger cone series, *Proaraucaria* (hence *P. patagonica* ♂). Secondly, there is also present a quite young growth stage of the larger ovulate cones. While preservation does not here extend to finer details of histologic structure, there is no mistaking this identification (likely with the robust cone type *P. mirabilis*). Moreover, as the sulcus between the bract and ligule is well defined, even before the position of the seed is outlined, this feature is not a deceptive generic character. And thirdly, there is a further new and well-represented generic type amongst the lesser cones, easily the most unique feature of the Cerro Cuadrado forest.

At first sight these latter cones appear to be those of pines about the size of the young highly colored cones of an Alcock's spruce three to five centimeters in length, with presence of a broad bract. But the sections at once show the structure to be intermediate between pines and Araucarians. Although the bract is more prominent than in any existing Abietinean, the seed scale makes up the main bulk of the cone, quite as in a pine, while the seed is single, pendent and enclosed, as in Araucaria. Minor structural details are not so well preserved as in some cycadeoid cones, though the larger features are distinct enough. The palisaded outer stone layer is clearly seen, with the nucellus rather free from the integuments; and in one of these cones embryos seem present, indicating an approximately mature condition.

In the case of cones so well represented and freely seen as these, a dozen of them having been cut, and with features so determinate and readily described, even without the illustration and comparison of the entire series of the Cerro Cuadrado yet to follow, descriptive names are fairly needed. Accordingly, it is suggested that on the basis of the distinct bract feature the new generic name *Pararaucaria* may be used. Also, as there is here, too, a more robust, fewer seeded and a more elongate form, the specific names *P. patagonica* and *P. elongata* suggest themselves. In both these forms the woody cylinder is relatively heavy, with the medulla small as in pines, and thus the reverse of the more typical Araucarian structure in these respects. No such types are known to me to be mentioned anywhere in paleobotanic records; but it would be very strange if further examples from elsewhere on the globe fail entirely in extant collections. If a cone-type from Neuquen, called by Spegazzini, *"Romeroites,"* is not rather to be referred to the *Pseudo-Araucaria* of Fliche, these stand as two related distinct genera, showing the presence within the Araucarian alliance of scale types with two or more seeds.

There, therefore, at last appear fossil types which go far to bring together the apposed branches of the Coniferales, and make of that stock a homogeneous unit. The long-debated question whether Araucarians or Pines are the precedent form becomes merely academic. Both are of much the same geologic age, and alike descendants of a well-defined Carboniferous stock with lax cones, various persistent relatives of which are recognizable in strata of Permian to Rhaetic age—*Palissya, Stachytaxus, Voltzia, Cycadocarpidium,* etc. By Permian time, the modern conifers are already defined, as more or less certainly proven by Florin. In Araucarians the bract is the main cone component, in pines the seed scale. In *Pararaucaria,* nature produced the intermediate form, made up of both bract and scale, which became extinct.

From these new points of view, Pines and Araucarians appear alike specialized. Either vegetatively, or in the cones, first one then the other shows that tendency to limited type and numbers after long ages have passed, that restriction to narrowed environments, that sharpness of feature called "specialization." Furthermore, let bract and scale be regarded as they may, the relatively little changed coniferalean stock must best be exemplified by the Podocarps, especially such a cone type as *Podocarpus andina.* Doubtless, a universal homology now runs through the entire group Coniferales taken as a true homogeneous stock. The older lax cone is then in some extremely simple sense antecedent to an inflorescence in which the fertile members merely arise in the successive bract axils. Or the cone is just a spiral succession of scale and fertile leaves, borne on an axis of limited growth. Much more could be said, but discussion better accompanies full illustration.

It is noteworthy that this world's second greatest of petrified forests occurs scarcely 10° south of the

present *Araucaria imbricata* forest of Argentina and Chile, testifying to extreme persistence of type. The counterpart in the northern hemisphere disappeared with the last of the dinosaurs. Two of the final well-marked species are the fine petrified cone *Araucaria hespera,* and the equally distinctive foliage type *Araucaria hatcheri* from the Ceratops beds of Wyoming and Dakota. Of the two great forests, the one yields the first clear glimpses of the Mesozoic flowering gymnosperms, the first readable evidence for the nature and place in geologic time of the course of change leading into the modern world of flowering plants; the other proves the Coniferales to be a homogeneous group, in all their later history at least.

G. R. WIELAND

FIELD MUSEUM,
YALE UNIVERSITY

SAMUEL BONSALL PARISH

LIKE many other amateur naturalists before him who have done things well, Samuel B. Parish carried on his botanical explorations of the native vegetation in Southern California because of the intellectual pleasures derived from field studies and because of his love of the high mountains and the stark deserts. Upon this area, Southern California, he has published no less than sixty-three papers ranging from problems of plant geography and taxonomic detail to topographic description, local lists, studies of immigrant plants and analyses of abnormal structures.

Born at Paterson, New Jersey, on January 13, 1838, he graduated from New York University in 1858, with the degree of B.A., taught school, served four years during the Civil War, pursued prospecting and mining in the western states and finally settled as a fruit-grower in the San Bernardino Valley of Southern California in 1872. This new home was centrally located and well situated for exploration by means of a camp wagon and horses of the varied topographic and climatic areas which make up the eight counties of Southern California, an area somewhat larger than the state of Pennsylvania. Botanically the region is highly interesting but was at that time an almost unexplored land. The fruitful results of expeditions made in days or weeks of leisure brought about between Mr. Parish and Dr. C. C. Parry, formerly botanist of the Mexican Boundary Survey, an intimate friendship, and through Parry there was established what were to prove relations, prolonged and cordial, with Asa Gray, George Engelmann, Edward Lee Greene, M. S. Bebb and many others. For a period of forty-eight years Mr. Parish continued to explore this region of his choice, his last expedition, a trip to the Campo region on the Mexican border, being made when he was eighty-one years of age.

On account of library and herbarium advantages he removed to Berkeley in 1920 and was soon appointed honorary curator in the herbarium at the University of California and a little later lecturer in botany at Stanford University. His library was purchased by Pomona College and his invaluable herbarium by Stanford University. He passed away at Berkeley on June 5, 1928, in his ninety-first year, having been active botanically until within a year of his death.

In 1915 Mr. Parish and Ellsworth Huntington joined forces for an expedition into the arid wastes of Death Valley. Both men had had much field experience and neither was in need of homilies on the thesis laid down by H. G. Wells in one of his books that a camping trip is the most severe test of human nature ever invented. On the return journey Dr. Huntington expressed a desire to meet Mrs. Parish. It was arranged. Said Dr. Huntington: "I have been curious, Mrs. Parish, to meet the woman who had the penetration to select so remarkable a man as Mr. Parish. I have in three weeks enjoyed him to the full."

The well-worn path that led to the door of the rose-covered Parish cottage in the San Bernardino Valley has been trod by scores of botanists, beginning with the early visits of Asa Gray and George Engelmann and coming on down to the later ones of Hugo de Vries and J. N. Rose. All these men and others who knew this quiet earnest worker had feelings akin to those of Dr. Huntington. Wise in foresight, thoughtful and considerate, generous of his store of botanical knowledge, unfailing in his dry and emollient humor, men were warmed by the wholesome personality of Samuel Bonsall Parish. In him the Wise Mother seemed in an unusual degree to have mixed harmoniously the ingredients of human nature.

W. L. JEPSON

UNIVERSITY OF CALIFORNIA

SCIENTIFIC EVENTS

THE INTERNATIONAL CONGRESS OF TROPICAL MEDICINE

THE International Congress of Tropical Medicine and Hygiene had its final meeting at Cairo on the morning of December 22 and the official proceedings ended in the evening with a *soirée* given by the organization committee in the Heliopolis Palace Hotel.

According to a report in the London *Times* the meeting was preceded by the ceremony, over which the Minister of Education, Ahmed Bey Lutfy es Seyyid, presided, of conferring honorary degrees of the Egyptian Faculty of Medicine on some of the foreign delegates. Professor Nuthall, Sir Robert Philip and

Sir Cooper Perry were among those created doctors of medicine.

At the final meeting it was decided that the next congress should be held in Holland in 1931, and it was unanimously resolved:

(1) That in view of the importance of anthropometric and morphological studies, not only to the classification of human races, but also to the ethnological aptitude of individuals, faculties and schools of medicine in tropical countries should specially study this question:

(2) That in view of the fact that leprosy is a disease menacing humanity, the governments of all nations represented in the congress should be invited to cooperate in systematic fashion to combat leprosy on the lines of discovering persons suffering from the disease, of organizing intensive ambulation treatment for early cases not discharging any organisms, of isolating comfortably lepers in an infectious stage, and of periodically inspecting their relatives.

The scientific side of the congress is said to have been most successful. Apart from communications on such subjects as Egyptian spleenomegaly, the prophylaxis of bilharziosis, of dysentery, of malaria and of trachoma, several cinema films dealing with tropical diseases were shown, some of great scientific value, particularly one dealing with the action of cells in the destruction of bacteria and another with the life history of bilharzia.

THE ENGINEERS MEMORIAL AT LOUVAIN

At a dinner of fifty covers at the University Club, New York, January 7, Prince Albert de Ligne, ambassador of Belgium to the United States, bestowed upon Chairman Edward Dean Adams, of the Committee on War Memorial of the American Engineers, the insignia of Commander of the Order of the Crown of Belgium, conferred by King Albert, as a mark of appreciation for the memorial carillon and clock placed by sixteen national American Engineering Societies in the tower of the new Louvain Library. This is the highest distinction conferred upon civilians of other countries by the government of Belgium. The Belgian Consul-General at New York, J. T. Johnston Mali, was among the guests. President R. V. Wright, of the United Engineering Societies, presided. The company included officers of the national engineering societies and other distinguished members of the engineering profession.

Mr. William H. Onken, member of the American Institute of Electrical Engineers and one of its delegates to the Louvain dedication last July, senior editor of *The Electrical World,* in the principal address after dinner, expressed the international significance of the American memorial, and its effect upon the citizens of Louvain. He also spoke of the notable contributions to human progress made by the Belgian and their fine personal qualities.

The ambassador expressed the deep appreciation of the King and the people of Belgium for the good will displayed by the engineering societies of the United States in placing in Louvain the memorial to the engineers of the United States who had given their lives in the Great War, and particularly for the leadership and generosity of Chairman Adams.

Chairman Adams accepted the distinction as an assurance of the friendliness between the two countries and proposed that the tower of the Louvain Library housing the memorial carillon and clock be named "Liberty Tower."

Mr. Henry W. Farnam, Jr., and Colonel Arthur S. Dwight showed motion pictures of the dedication of the Louvain Library last fourth of July, which they had taken during the ceremonies. A short report was presented by the Committee on War Memorial.

STORM DAMAGE TO THE EXPERIMENT STATIONS IN THE WEST INDIES AND FLORIDA

The tropical storm which swept the West Indies and Florida from September 10 to 17 caused, as we learn from *The Experiment Station Record,* much damage to both the Porto Rico and Virgin Islands Experiment Stations. No lives were lost, and none of the station employees or their families were injured, but the damage to crops, experimental orchards, buildings and fences was very severe.

The storm struck the island of St. Croix during the night and early morning of September 12 and was accompanied with heavy rain that continued for three days. There was general damage all over the island, but fortunately comparatively few lives were lost. At the station a number of buildings, mostly residences of the employees, were partly unroofed, but little damage was done to the office and laboratory building. The plant house, poultry house, implement shed and fumigating house were destroyed completely, as was a large galvanized iron shed used as a catchment area for the water system. The damage done to the buildings and fences is estimated at about $5,000.

In Porto Rico the hurricane swept the island on September 14, doing enormous damage to buildings, crops and trees. There was a large loss of life, more than 1,000 fatalities being reported. The damage to the island is estimated at from $60,000,000 to $100,000,000. The citrus and coffee crops, both of which were very promising, were almost totally lost and the plantings so severely damaged that four or five years will elapse before conditions are again normal.

At the station, which is located at Mayaguez, a por-

tion of the island where the storm was somewhat less severe than in other parts, the damage to the property was still very great. A number of the buildings were unroofed, and some of the laborers' houses were so badly wrecked that they will have to be rebuilt. The office and laboratory building was not damaged to any considerable extent. The heavy rain accompanying and following the storm caused considerable injury to the contents of the unroofed buildings. Several of the smaller station buildings were utterly demolished, and the loss to the station property is estimated at $10,000. The experimental crops and orchards of tropical fruits, forestry plantings, etc., were destroyed to a large extent, necessitating beginning them anew.

At both stations temporary repairs have been effected, and work is proceeding, although it will be some time before some projects can be resumed.

The principal damage to the station property in Florida was at the Everglades Experiment Station, situated near Belle Glade. Here, likewise, there was no loss of life, but the damage to buildings and equipment is estimated at nearly $35,000, irrespective of breaks in the levees. On September 16 and 17 the station lands were flooded by water from Lake Okechobee to a maximum depth of about 43 inches, destroying all field plats, a citrus planting, all meteorological instruments, many supplies, etc. Many of the buildings were unroofed, twisted and moved from their foundations, and several were demolished completely. Among these was the greenhouse, aside from the service room which is practically intact. There was also extensive damage to books and laboratory equipment. Although the flood waters receded very slowly, salvage work was taken up promptly, and it is expected that the operation of the station will be continued.

THE PROGRAM OF RESEARCH OF THE CORN-BORER CONFERENCE

A COMPLETE program of research for controlling the European corn borer was presented and adopted at the third annual conference of corn-borer interests in Washington, D. C., on January 2. More than seventy representatives from the corn-borer infested states and the corn belt, including entomologists, administrative officials and others interested in the problem, attended the meeting.

Dr. A. F. Woods, director of scientific work, U. S. Department of Agriculture, as chairman of the conference, opened the day's session by a brief address in which he urged a free discussion of the many angles of the problem and explained the purpose of the conference was to provide for a complete coordination of the various research projects throughout the affected States and Canada.

The program as adopted for 1929 includes definite research work by six bureaus of the U. S. Department of Agriculture—Entomology, Plant Industry, Chemistry and Soils, Public Roads, Animal Industry and Agricultural Economics. Seven states—Illinois, Indiana, Michigan, Ohio, New Hampshire, Pennsylvania and New York—also will carry on research and educational work in the numerous phases of the borer problem.

Among the thousands of major and minor lines of investigation all of which have an important bearing on the final solution of the problem will be studies by these federal bureaus and states on feeding and otherwise using cornstalks, breeding experiments to produce strains that may prove tolerant to the borer, studies of fertility treatments to hasten development of the corn plant so as to miss the maximum moth flight, and studies on the possibility of displacing the corn plant with other crops of equal value.

Investigations with insecticides, repellants and attractants will be conducted. The important projects now under way to introduce and establish parasites of the borer from foreign countries will be continued. Studies of the life habits of the pest will be carried on to furnish information necessary for a practical program in combating spread and control of the borer.

Effort will be continued to determine the value of fall and spring plowing in different types of soil, with different widths and types of plow bottoms, on different dates, and at various depths.

In fact, no line of investigation that promises to furnish useful information on the borer problem has been omitted from the 1929 program. A new committee representing the American Society of Animal Production reported at the conference and pointed out that 80 per cent. of the corn produced is fed to livestock. Therefore, the committee stated, any menace to the corn crop is of vital interest to the animal husbandman. In this connection the 1929 program includes studies on the use of other feeds and pastures in greater quantities to meet a possible shortage of corn.

PROGRAM OF THE AMERICAN PHILOSOPHICAL SOCIETY

DR. FRANCIS X. DERCUM, president of the American Philosophical Society, has appointed a committee of forty-two members whose objectives are an "intellectual stock-taking" in order to plan a program of development for the society. In his letter to members Dr. Dercum writes:

The American Philosophical Society, having crossed the threshold of its third century, enters upon the New Year

resolved to continue and to expand its service to learning. For more than two hundred years the society has kept pace with America's progress. Through all the years to come it pledges its membership to its original ideal and purpose—"promoting useful knowledge."

But at the present time the society is faced with a problem which for solution will require the cooperation of the entire membership. Since Benjamin Franklin gathered about him in 1727 his "ingenious acquaintance into a club for mutual improvement," many and marvelous changes have taken place in this world of ours. As the nation has progressed, hundreds of learned societies have followed in the wake of this first gathering of intellectual leaders.

Because of this growth and of the natural need for a great many special societies, it is becoming more and more necessary to unite the intellectual leaders of to-day in one coordinating effort for mutual understanding and the promotion of useful knowledge.

"Unless there is a period of intellectual stock-taking," said Professor C. Lovatt Evans, of University College, London, before the British Association for the Advancement of Science, "there must inevitably be a loss of perspective and of grasp of great general principles."

The American Philosophical Society is taking stock of the intellectual situation with a view to formulating a future program of service to all branches of learning through its membership. As one of our distinguished members said for us at our bi-centenary celebration in 1927 and as others of us have often emphasized:

"The intertwining of philosophic and humanistic interests in the Philosophical Society helps not merely in deepening our perspective in the field of knowledge. It serves also to make more clear the meaning of development of human interests through time. In a day of natural and proper specialization such an organization serves as stabilizer and a means for helping to make more clear the relation between man and his environment, and the place of the individual in the scheme of human organization.

"The two hundred years of history behind us have seemed perhaps to make more wide the gaps between our various departments in the scheme of knowledge. Before us lies an opportunity for service in picturing through synthesis of these divergent elements a universe of nature and of human life more wonderful than that which we have known and destined to give us ever increasing joy of living."

With our opportunity thus clearly defined, I have appointed a committee on development of the society's activities. This committee has as objectives the intellectual stock-taking necessary to the projection of a program of continuing and expanding service of the society and the final development of that program.

Already the members of the committee, chosen from various parts of the country, have proffered their views for such a program. Within a short time a report will be made.

Upon the devotion of the members depends the society's opportunity for the successful execution of this program.

The members of the committee are:

Francis X. Dercum, *chairman;* Cyrus Adler, Philadelphia; John Ashhurst, Philadelphia; Frank Aydelotte, Swarthmore; James H. Breasted, Chicago; Ernest W. Brown, New Haven; Albert P. Brubaker, Philadelphia; William W. Campbell, Berkeley; Edward Capps, Princeton; Edwin G. Conklin, Princeton; Arthur L. Day, Washington; Henry H. Donaldson, Philadelphia; Joseph Erlanger, St. Louis; Livingston Farrand, Ithaca; John H. Finley, New York; Arthur W. Goodspeed, Philadelphia; Victor G. Heiser, New York; William J. Holland, Pittsburgh; Arthur E. Kennelly, Cambridge; William E. Lingelbach, Philadelphia; Edgar Odell Lovett, Houston; Daniel T. MacDougal, Tucson; Clarence E. McClung, Philadelphia; Walton B. McDaniel, Philadelphia; Lafayette B. Mendel, New Haven; John A. Miller, Swarthmore; Robert A. Millikan, Pasadena; Henry Fairfield Osborn, New York; Raymond Pearl, Baltimore; R. A. F. Penrose, Jr., Philadelphia; William Lyon Phelps, New Haven; Eli Kirk Price, Philadelphia; Henry S. Pritchett, New York; Charles Lee Reese, Wilmington; Leo S. Rowe, Washington; Frank Schlesinger, New Haven; William B. Scott, Princeton; Harlow Shapley, Cambridge; Witmer Stone, Philadelphia; Elihu Thomson, Swampscott; Oswald Veblen, Oxford; Edwin B. Wilson, Boston.

SCIENTIFIC NOTES AND NEWS

HERBERT HOOVER has received the congratulations of a committee representing the American Philosophical Society, of which he has long been a member. The engrossed scroll presented to the President-elect bears the following inscription: "To scientific knowledge and technical skill, to a devotion to humanities you join a wide experience in public affairs at home and abroad and you thus exemplify in your person that happy combination of the natural and moral philosophies which this society has cherished since the day of its founding by Benjamin Franklin. We feel assured that the selection of a member of the society, devoted as you have been to scientific studies and to their application to the furtherance of noble humanitarian projects, will be in the minds of the people of this country a symbol of that intellectual statesmanship so necessary for the right proportion between the ideals for which we live and the material and physical prosperity which, though necessary to every nation, must never become its sole concern." Mr. Hoover is the ninth member of the American Philosophical Society to be elected president of the United States.

AT the meeting of the Botanical Society of America in New York City, Professor Margaret C. Ferguson, chairman of the department of botany at Wellesley College, was elected president for 1929.

DR. ALEŠ HRDLIČKA was elected president of the Washington Academy of Sciences at its annual meeting held on January 8.

DR. WILLIAM BOWIE, chief of the division of geodesy of the U. S. Coast and Geodetic Survey, has been elected a corresponding member of the Academy of Sciences of the Institute of France.

DR. WILLIAM H. EYSTER, professor of botany in Bucknell University, has been elected a member of the German Botanical Society.

AT a meeting of The Academy of Natural Sciences of Philadelphia held on December 18 the following were elected correspondents: Eugene Louis Bouvier, Philippe Dautzenberg, Benjamin M. Duggar, Edward Murray East, Amadeus William Grabau, Carl E. Hellmayr, Arthur Keith, Albert Mann, F. Ris, Charles Wardell Stiles, Walter F. Swingle, Richard Wettstein v. Westersheim and Arthur Smith Woodward.

THE doctorate of science has been conferred by the University of London on Major Greenwood, professor of epidemiology and vital statistics in the university.

DR. H. D. ARNOLD, director of research of the Bell Telephone Laboratories of New York, has been awarded the John Scott medal by the Franklin Institute of Philadelphia in recognition of his work in developing the three-electrode high-vacuum thermionic tube. In addition to the medal a certificate and a premium of $1,000 were presented to him.

THE prize of the American Foundrymen's Association has been awarded to H. T. Wensel and W. F. Roeser, respectively, physicist and associate physicist of the section of pyrometry of the Bureau of Standards, for a paper giving certain corrections which must be applied to optical pyrometer readings in determining the temperature of molten cast iron. The prize will be presented at the annual convention of the association, which will take place in Chicago in the spring.

THE American Association of Textile Chemists and Colorists has made an award of $100, their prize for the best paper presented before the association during the year, to Dr. Carl Z. Draves, of the technical laboratory of the E. I. du Pont de Nemours and Company, for his paper on the use of the spectrophotometer in estimating the strength of dyes.

THE Buchan prize of the Royal Meteorological Society for 1929 has been awarded to Dr. Harold Jeffreys for papers contributed to the *Quarterly Journal* of the society during the years 1924–27 on cyclones, fluid motions produced by differences of temperature and humidity, dynamics of winds and various other subjects. It was planned to present the medal to Dr. Jeffreys at the annual meeting of the society on January 16.

DR. JAMES F. MCKERNON, retiring president of the New York Post-Graduate Medical School and Hospital, was the guest of honor on January 9 at a dinner at the Hotel Biltmore attended by 500 members and guests. Dr. McKernon has been connected with the Post-Graduate Medical School for thirty years and has now been elected its honorary president. Tribute to Dr. McKernon's service both at the Post-Graduate Medical School and as head of its medical unit in France during the war was paid by Dr. J. T. M. Finney, of the Johns Hopkins University, surgeon-in-chief of the A. E. F.; Dr. Livingston Farrand, president of Cornell University; the Reverend Dr. Karl Reiland, rector of St. George's Episcopal Church, and Dr. Edward H. Hume and Dr. Arthur F. Chase, of the Post-Graduate faculty. Dr. Marshall C. Pease presided.

THE marriage of Dr. James W. McBain, professor of chemistry at Stanford University, and Dr. Mary Evelyn Laing, assistant professor in the same department, took place in the Stanford Memorial Church on January 1.

PROFESSOR A. A. TITSWORTH has retired after forty-two years of service in the mathematical department of Rutgers University.

DR. GEORGE OTIS SMITH, director of the U. S. Geological Survey, has been elected a member of the board of trustees of the University of Chicago.

DR. CHARLES E. RIGGS, medical director in the U. S. Navy, has been nominated for surgeon-general and chief of the bureau of medicine and surgery of the Department of the Navy, in succession to Rear-Admiral E. R. Stitt.

DR. MARSHALL C. BALFOUR has been assigned to the New York City office of the International Health Division of the Rockefeller Foundation to succeed Dr. Charles N. Leach, who will be transferred this month to a post in Europe.

HORACE M. ALBRIGHT, superintendent of Yellowstone National Park and field assistant director of the National Park Service, has been designated as acting director of that service during the illness of Stephen T. Mather, its director.

DR. M. C. MERRILL has been appointed chief of publications in the Office of Information, Department of Agriculture, and Frank D. Smith as assistant chief of publications in charge of operations. Dr. Merrill has been acting chief of publications since last July.

Mr. Smith has been in charge of the printing done for the department.

LOYD V. STEERE, associate agricultural commissioner in the foreign service of the Bureau of Agricultural Economics, who has been stationed in Berlin, Germany, has been designated as agricultural commissioner in charge of the Berlin office of the bureau, effective January 1. Mr. Steere was sent to Berlin in July, 1926, as assistant to George C. Haas, then in charge of that office. When Mr. Haas returned to Washington in July, 1927, Mr. Steere assumed full charge. Coincident with Mr. Steere's promotion, Owen L. Dawson, senior economist of the division of statistical and historical research of the bureau, will go to Germany to act as assistant agricultural commissioner.

PROFESSOR L. N. G. FILON has been appointed for a period of five years director of the observatory of the University of London. C. C. L. Gregory has been appointed "Wilson observer."

DR. JOHN P. KINLOCH, head of the public health department of Aberdeen University, has been appointed chief medical officer in the department of health for Scotland. On January 1 he took over the duties of the Scottish Board of Health.

J. D. BELZILE, formerly assistant superintendent of Demonstration Farms in the Province of Quebec, which position be held for six years, has been appointed assistant to the chief supervisor of illustration stations in the experimental farms branch of the Dominion Department of Agriculture, Ottawa.

DR. H. B. HUNGERFORD, state entomologist and head of the department of entomology at the University of Kansas, has returned from an eight-months' visit to Europe, as collaborator for the Smithsonian Institution, where he went for the purpose of comparing insects in the University of Kansas collection with the type collections in the older museums of Europe.

DR. P. A. M. DIRAC, of St. John's College, Cambridge, England, will be in residence at the University of Wisconsin during April and May of the present year, giving lectures in quantum mechanics in the department of physics.

AT the annual meeting of the New York Academy of Medicine on January 3, the retiring president, Dr. Samuel W. Lambert, spoke on "The Academy as an Educational Center," and the incoming president, Dr. John A. Hartwell, on "The Academy, the Profession and the Public."

DR. FREDERICK CHEEVER SHATTUCK, long connected with the Harvard Medical School faculty until he became Jackson emeritus professor of clinical medicine in 1912, died on January 11 in his eighty-second year. Dr. Shattuck was an overseer of the university from 1913 to 1919.

DR. WILLIAM H. DAVIS, chief of the division of vital statistics of the Bureau of the Census, died on January 6.

PROFESSOR ERICH BECHER, of the University of Munich, died on January 6, at the age of forty-six years. A correspondent writes: "He studied at the University of Bonn, receiving his degree from this institution in 1904. In January 1907 he was appointed privat dozent at the University of Bonn. In 1909 he was called as professor of philosophy to the University of Munich. His activities are expressed in the development of the psychological institute, which now enjoys a world-wide reputation. Dr. Becher attended the International Congress of Philosophy held at Harvard College in September, 1927, contributing two papers at its meetings. Besides being a member of many of the leading societies of Europe he was also a member of the Washington Academy of Sciences."

A MEMORIAL academic building in honor of the late Henry Burchard Fine, of Princeton University, is to be erected on the university campus. For this purpose Thomas D. Jones, of the class of '76, and his niece, Miss Gwethalyn Jones, have given $500,000. Construction of the new building will be begun this spring. It will be devoted to the departments of mathematics and mathematical physics and will be known as the Henry Burchard Fine Mathematical Hall. The Henry Burchard Fine professorship of mathematics, now held by Professor Oswald Veblen, was endowed by Mr. Jones in 1926.

A JOINT meeting of the Optical Society of America and the American Physical Society will be held in New York at the physical laboratory of Columbia University on Friday and Saturday, February 22 and 23.

THE winter convention of the American Institute of Electrical Engineers will be held in the Engineering Societies Building, New York, January 28 to February 1.

THE eighth annual convention of the American Society of Clinical Pathologists will be held in Portland, Oregon, beginning on July 5.

THE twelfth exposition of Chemical Industries will be held at the Grand Central Palace, New York, from May 6 to 11.

INSTRUCTIONS have been given to a Toronto firm of architects to prepare plans and specifications for research laboratories to be erected in Ottawa. It is

announced that the first buildings will cost $1,000,000 and these will later be added to, bringing the total cost to $3,000,000. This expenditure is what Premier King had reference to when he told a delegation from the Trades and Labor Congress that the government's contribution to technical research would exceed by many times what it had been contributing to technical education.

FRANCIS P. GARVAN, head of the Chemical Foundation, has given $10,000 to the Johns Hopkins University for the enlargement of the laboratory of Dr. Joseph Colt Bloodgood for the study of human cancer, particularly in reference to the use of dyes and stains in its diagnosis in its earlier stages and treatment and in the investigation of such problems as may arise.

MR. AND MRS. GEORGE H. ROOS, San Francisco, have given the University of California $100,000 in memory of Mrs. Roos' parents, J. J. and Nettie Mack, to be used in the medical school for the study of cancer and surgical diseases of the chest. Only the interest will be used for research. The fund, which will be known as the J. J. and Nettie Mack Memorial Foundation, will be governed by a committee of the medical faculty. The Hooper Foundation will cooperate in this work.

THE National Geographic Society has made a grant of $10,000 to continue its expedition in cooperation with the Smithsonian Institution at Mt. Brukkaros, South West Africa, for the study of solar radiation. Dr. Abbot has had general supervision of the construction of a 12-inch square stellite plane mirror for the laboratory under Dr. D. T. MacDougal's care at Tucson, Ariz. This, the largest stellite mirror which has ever been made, was figured by Mr. M. E. Kahler, of Georgetown. The advantage over the ordinary silver-on-glass optical mirror is in its freedom from tarnishing. Several stellite mirrors 12 years old in the possession of the Astrophysical Observatory are as bright as ever.

THE Carnegie Foundation has made a grant of $25,000 to Princeton University for the study of light conditions under which atoms exist. The research, to be carried on by the Princeton department of physics and astronomy, is to supplement that now going on at the Mount Wilson Observatory under the auspices of the Carnegie Foundation.

UNIVERSITY AND EDUCATIONAL NOTES

A BEQUEST of $225,000 for building a new wing to the Yale Medical School is contained in the will of the late Dr. Thomas F. Smallman, a Brooklyn surgeon. The bequest is effective after the death of the widow, Mrs. Jane U. Smallman, who receives the income during her life. The proposed building is to be known as "The Jane Smallman Wing for the Treatment of the Sick."

DARTMOUTH COLLEGE is named as the ultimate beneficiary of the estate of Mrs. Jeannette I. Cummings, who died on December 12. The bulk of the estate, estimated in excess of $500,000, is to be turned over to the college on the death of her sister for the erection of a memorial to her husband.

DR. FRANK CLIFFORD WHITMORE, head of the department of chemistry at Northwestern University, has been appointed dean of the school of chemistry and physics at the Pennsylvania State College. Dr. Whitmore succeeds Dr. G. L. Wendt, who has been appointed assistant to the president in charge of research.

DR. JOSEPH TRELOAR WEARN, associate professor of medicine in the Harvard Medical School, associate director of the Thorndike Memorial Laboratory and visiting physician to the Boston City Hospital, has been appointed director of medicine at Lakeside Hospital and head of the department of medicine of the school of medicine of Western Reserve University. Dr. Wearn's appointment will fill the vacancy left in June, 1927, by the death of Dr. Charles Franklin Hoover, who had occupied the chair of medicine since 1909.

DR. MILO HELLMAN, associate in physical anthropology in the American Museum of Natural History and hitherto professor of comparative dental morphology, has been appointed professor of orthodontia and head of the department at the New York University College of Dentistry.

C. B. HUTCHISON has been appointed director of the Giannini Foundation of Agricultural Economics, professor of agriculture at the University of California and associate director of research at the station.

DR. H. S. JACKSON, of Purdue University, has accepted a professorship in mycology and cryptogamic botany at the University of Toronto.

DISCUSSION AND CORRESPONDENCE

THE MISSING LINK IN STELLAR EVOLUTION

I HAVE read with unusual interest the leading article "Available Energy" by Professor Millikan, in SCIENCE of September 28, and wish to add an astronomical

"bit" on the following points: (*A*) An atom-creating process continually taking place in interstellar space; (*B*) the relation between mass and energy.

For many years I have been actively interested in the evolutionary processes in our stellar universe, and due to the paralysis of our improvements here during and after the war, additional time for these problems has been available. From force of circumstances, and from the nature of the problem itself, these investigations covered a wide field, were often disconnected and in little-trodden paths.

It very early became obvious that there must be building-up processes of some kind, at least of matter already formed. For how else could be explained the changes in a system where so much cosmical matter existed? And where has this matter come from? As evidence of such processes it is only necessary to cite what is probably the most outstanding example, the case of Lockyer's meteoritic theory of stellar formation which is now generally accepted as best satisfying observed phenomena. Comets, meteor swarms and probably the asteroids are other examples. If the stars (and sun) are built-up bodies it would be difficult to deny a similar origin to the planets and satellites.

The disintegration of matter into energy seems to be satisfactorily established and we must either reject the evidence of building-up processes or admit the logic of reversibility or of assuming that the energy which is being radiated constantly from the stars is transformed in some way in the interstellar regions. No one-way hypothesis is in harmony with many of nature's processes which come under observation in our everyday experience, such, for example, as the cycles of life in the animal and vegetable worlds.

The farther my vision extended the more logical and necessary seemed an evolutionary cycle or orbit, in which we might liken degeneration or disintegration as corresponding to perihelion, periastron or pericosmon and regeneration to aphelion, apastron or apicosmon.

I have been unable to find any logical objection or definite evidence against a regeneration of matter—that it had not actually been detected was not considered crucial.

Such in outline is the reasoning which gradually took shape from consideration of the facts of observation, and led tentatively to the hypothesis of transformation of radiation into fundamental matter or its predecessor, in the outer spaces, and which finally became a definite conception of the connecting link. But I could find no direct evidence of such a transformation until some two years ago, when I encountered relationships among the periods of celestial bodies which seemed to bear on the general problems of atomic structure and motion.

These will be considered under *B*.

Now, however, Millikan and his associates find powerful, penetrating rays which, by a process of exclusion, they conclude must come from interstellar space. They have gone further and have determined the energy emitted in the creation of atoms of the most common elements and their absorptions, which agree satisfactorily with observations of the absorptions of these cosmical rays.

From this they infer that these cosmic rays are the evidence of the formation of matter in the interstellar spaces. I have little doubt they are right and as already stated my experience and investigations along different lines led me to a similar hypothesis.

The object of this communication is not to offer my hypothesis of the formation of matter in interstellar spaces except as a modest confirmation but to call attention to other evidence.

A

There is a class of body which is very much of an anomaly to astronomers and one which is difficult to locate satisfactorily in almost any scheme of cosmogony, the cosmical nebulae (spiral and globular, often called the white, nebulae).

The peculiar relation of these nebulae to the galaxy and their high velocities of recession have been difficult to explain. The most rational explanation which has yet been offered is that they have been formed from matter which has been ejected from the galactic stars by light pressure.

One difficulty which that hypothesis seems to encounter is the amount of matter which must have been so ejected—perhaps as much as the present galactic system of stars contains—and which also leaves the destiny of the enormous amount of energy radiated from the stars still unexplained.

If, however, these nebulae are composed of matter which was ejected as simple radiation or energy or motion, and that, by the atom-building process in the interstellar spaces which Millikan and his associates are tracking down, were built up out there, some of these difficulties disappear. For the quantity of radiation sent out seems to be of a far higher order than the cosmical matter that could be so ejected.

These cosmical nebulae and the hypothesis of atom-building in the interstellar spaces appear, therefore, to mutually support each other.

B

While investigating periodic preferences among the Cepheid variables and spectroscopic binaries I was led to examine the periods of revolution and rotation

of the planets and satellites of our solar system and the periods of revolution of visual binary stars. More than an accidental number of preferences for the same periods were found in a variety of these motions. In addition it was found that there was a tendency in many if not all of them for the periods to fall into series and sequences of one half or two times the adjacent periods.

The binary stars also showed preferences for certain periods, and—what was the most astonishing of all—there appeared to be some kind of correlation between these periodic phenomena and the atomic weights of the elements.

In a paper "On the Nature of Stellar Variability"[1] were published some of the results for the different classes of variable stars and reference was made to preliminary examination of the planets and satellites of the solar system. The results for the binary stars and the apparent correlation with atomic phenomena have not yet been published.

It is not possible to give here the evidence on which the relationships referred to rest, and circumstances over which I had no control have prevented up to the present further prosecution of those investigations or attempts to publish them. I hope to go further with this work and to publish what has already been done. Time has not weakened the strength of the data.

Briefly, the correlations referred to are between the periodic phenomena of widely divergent kinds, such as pulsations in stellar envelopes and orbital periods, and these in turn with atomic phenomena. Such correlations, if real, must have some kind of underlying relationship of a very fundamental nature. Although the mechanism and the steps are not evident, the idea is at once suggested that some form of motion may be the link, that here we may be encountering the relationships between mass and energy or motion, or perhaps simply transformations of energy. Such apparent relationships recall the speculation that matter is only frozen motion.

These correlations, if general, would imply an intimate relationship between widely differing units, such as the day, year and atomic properties. It is to be remembered, however, that these all reduce to time and motion.

The transformation of matter into energy appears to be satisfactorily established, and with the cosmic rays indicating the building up of atoms, it seems no far cry to a relationship between atomic motions and those of large aggregations of atoms. The law of gravity applies to the smallest meteoric particle as well as to the largest star.

For the present I can do no more than call attention to these periodic phenomena and their possible bearing on some of the fundamental problems of cosmogony. To the future must be left the final decision as to their reality and their nature.

[1] *Ast. Nach.*, 5505, Band 230, 1927.

CORDOBA, ARGENTINA, C. D. PERRINE
OCTOBER 30, 1928

RESONANCE RADIOMETRY

THE limiting sensitivity of any radiometric system is reached when spurious deflections become comparable with real deflections. Beyond this point optical magnification, increased period, etc., are of no avail. An attempt is here made to reduce the relative effect of spurious disturbances by causing the radiations from a real source to be intermittent with a definite period, and to "tune" the entire system to be period of intermittency. The system, though not limited to any definite radiometric device, does make use of the principle of resonance—hence the name "resonance radiometry."

To be specific: a single-junction thermopile (I) of the type developed by the writer was exposed to radiation at intervals of 0.75 seconds by means of a pendulum having a period of 1.5 seconds. The thermopile (I) was connected to a low-resistance, underdamped D'Arsonval galvanometer (I) tuned to a period of 1.5 seconds. A concave mirror attached to this galvanometer made it possible to project the image of a coarse grid (consisting of bars 2 mm wide and 2 mm apart) on a second grid of the same spacing. This second grid was "split" centrally so that the image of the first grid, when in motion, would increase the amount of light transmitted on one side and decrease the light on the other side. By means of a split lens, the light passing through the second grid was brought to two foci on the respective junctions of a three-element compensating thermopile (II), also of small heat capacity. This thermopile (II) was connected to a second D'Arsonval galvanometer (II) having the same period of 1.5 seconds. The light falling on thermopile (II) was derived from a small auto headlight lamp.

Both galvanometers were of rugged construction and of relatively low sensitivity. Due to the circumstance that the entire system was "tuned," a high degree of immunity from spurious (non-intermittent) disturbances was realized.

The sensitivity actually obtained is as follows: With a candle at one meter from thermopile (I), the radiation passing through an aperture of one square millimeter at the above distance occasioned a deflection of 2,000 mm on the meter-scale of galvanometer (II). This sensitivity already rivals that of the best instruments now employed.

In later experiments, thermopile (II) was replaced by a vacuum-tube amplifier embodying a photoelectric cell. By means of this, the above sensitivity was increased, approximately 1,000 times. At the present

time, efforts are being concentrated on imparting to galvanometer (I) the great stability which is essential to high amplification.

A. H. PFUND
THE JOHNS HOPKINS UNIVERSITY,
DECEMBER 28, 1928

HALL EFFECT IN SINGLE METAL CRYSTAL

IN SCIENCE for August 24, 1928, a report on measurements of the Hall Effect in single crystals of silicon steel stated that no change in this effect with change in crystal orientation had been found. It was further stated that such changes probably should not be expected in metals following the cubic lattice structure but might be expected in some other structure. Recently measurements have been made on a large zinc crystal of the close packed hexagonal system and the Hall Effect was found to be about 50 per cent. larger in the single crystalline portion than in the polycrystalline portion.

P. I. WOLD
DECEMBER 12, 1928

DISSOCIATION OF NEUTRAL VACCINE VIRUS–IMMUNE SERUM MIXTURES

IT has been shown that the mixture of a virus and its specific anti-serum which is innocuous when introduced into the animal organism becomes disease-producing after dilution with appropriate amounts of Ringer's solution.[1, 2] Certain aspects of this reaction have led us to conclude that the dilution phenomenon resembles the hydrolysis of the salt of a weak acid and weak base, and that the observed dissociation probably follows the law of mass action. This is indicated by results obtained from qualitative studies of the degree of dissociation following dilution of neutral and over-neutralized mixtures of vaccine virus and immune serum, from cataphoresis experiments, and from the observation that the dissociation is reversible.

PERRIN H. LONG,
PETER K. OLITSKY
THE ROCKEFELLER INSTITUTE
FOR MEDICAL RESEARCH,
NEW YORK CITY

PRICKLY PEAR WORK

IN SCIENCE for September 14, page 241, there is a reference to a paper contributed by Dr. R. J. Tillyard to the Fourth International Congress of Entomology. This appears to imply that the work on entomological control of prickly pear in Australia has been carried out by Dr. Tillyard himself, though I am sure that he had no intention of conveying such an idea when presenting his paper.

As the prickly pear work in Queensland is attracting considerable attention and promises to be highly successful, it might be worth while just briefly to place on record the history of its control.

The first step was taken in 1912 when, at the instance of the Queensland government, Dr. T. Harvey Johnston and Mr. Henry Tryon spent eighteen months visiting various parts of the world where prickly pears exist, investigating the natural enemies of the plant. As a result the Indian cochineal was introduced and rapidly destroyed the smooth tree pear, *Opuntia monacantha*, in the districts where it occurred. The pest pears (*inermis* and *stricta*) were least affected. In 1919 the governments of the Commonwealth, New South Wales and Queensland entered into a cooperative agreement and for five years carried out experiments to determine thoroughly the possibilities of biological control. The Commonwealth Prickly Pear Board was constituted in 1920 to undertake the work, and the agreement between the three governments was renewed in 1925 and again two years later. It expires on May 31, 1930. The present members of the board are: Mr. F. D. Power, chairman of the Queensland Prickly Pear Commission; Mr. G. D. Ross, under secretary for agriculture, New South Wales; Mr. Gerald Lightfoot and Professor E. J. Goddard, representing the Commonwealth Council for Scientific and Industrial Research. The annual vote available to the board has recently been increased, and now amounts to £18,000 per annum, of which the Commonwealth provides half.

The scientific work was under the control of Professor T. Harvey Johnston from the inception of the board to February, 1923; of Mr. J. C. Hamlin from then to May, 1924; of Mr. W. B. Alexander from that date to August, 1925, while Mr. Alan P. Dodd has been in charge since October, 1925. Biologists are at work both in North and South America, and in Australia there is a central receiving laboratory and quarantine station near Brisbane and breeding and acclimatizing stations elsewhere in Queensland and New South Wales. The scope of the work includes:

(a) The study of all prickly pear insects in their native country.
(b) The breeding of material free from parasites and predators.
(c) The testing of these insects against crops and other plants.
(d) The forwarding of selected kinds of insects to Australia.
(e) Their breeding and acclimatizing under local conditions.
(f) Their establishment in the open at various localities on our several pest pears.

Numerous insects have been introduced, of which by far the most successful to date is *Cactoblastis cac-*

[1] Todd, C., *Brit. Jour. Exp. Path.*, 1928, ix, 244.
[2] Andrewes, C. H., *Jour. Path. and Bact.*, 1928, xxxi, 671.

torum, which was brought by Mr. Dodd from Argentine in March, 1925.

A. C. D. RIVETT
COMMONWEALTH COUNCIL FOR
SCIENTIFIC AND INDUSTRIAL RESEARCH,
AUSTRALIA

REPORTS

THE INFLUENZA EPIDEMIC[1]

WHEN influenza is prevalent or is believed to be approaching a community during the course of an epidemic it is advisable to take advantage of the public interest and concern, and by emphasizing anew those public precautions and practices of personal hygiene upon which the prevention of communicable affections of the upper respiratory tract depend.

Measures for precaution fall naturally under those of a communal or administrative character and those which apply to the individual.

1—Efforts should be made to reduce the opportunities of direct-contact infection by avoiding crowds.

2—Schools or colleges should not be closed wherever adequate medical and nursing supervision is available, and provision is made for the prompt exclusion of all persons showing suspicious catarrhal symptoms, especially when these are associated with a rise in temperature.

3—The reopening of boarding schools and colleges after vacations should not be encouraged in the presence of epidemic influenza unless there are generous accommodations for the bed care of those who may be attacked.

4—While the general closing of places of public assemblage is to be deprecated, there may be local conditions justifying such action at the discretion of the local health authorities.

5—In groups which can be brought under daily professional inspection the isolation of early and suspicious cases of acute respiratory tract infection, particularly when these are accompanied by rise in temperature, may result in delaying the spread of the disease.

6—In isolated communities and in institutions infection may be delayed and sometimes be avoided by the strict exclusion of visitors.

7—The person and sickroom of infected individuals must be considered a definite focus of infection, and visits to such persons or premises should be avoided by all persons except the necessary medical and other attendants.

When influenza prevails or threatens, information on the subject of cleanly personal habits and personal hygiene should be spread widely, particularly with regard to the following points:

1—Avoidance of all uncovered acts as coughing, loud talking, sneezing or spitting.

2—Special emphasis upon the need of washing the hands frequently, more especially before eating; unclean articles and fingers should be kept out of the mouth and nose. This advice is particularly applicable to all persons in attendance upon the sick.

3—Avoidance of exposure, fatigue and any bodily excess.

4—Persons in good health should continue in their normal manner of life.

It would seem advisable that in the presence of influenza or upper respiratory infections individuals should make more than the ordinary effort to increase well-being. This may be obtained by:

1—Securing adequate sleep and rest (eight to ten hours' sleep every night with windows open, but under enough covering to keep warm).

2—Eating a moderate, mixed diet and partaking freely, at regular periods, of pure water (six or eight glasses daily).

3—Wearing clothing to suit the environment, particularly clothing which prevents chilling of the body surfaces and which keeps the body dry.

4—Avoiding people with colds, especially those who are sneezing or coughing. There is more danger from contact with those just beginning to feel sick than from those ill enough to be confined in bed.

5—Keeping out of crowds as far as possible, especially crowds in closed places.

6—Avoiding the use of common towels, wash basins, glasses, eating utensils and toilet articles.

7—Washing the hands thoroughly before eating.

8—Avoiding the use of so-called preventatives. Vaccines, sera and advertised preventatives seem to be of no value and may be harmful in this disease.

9—Avoiding alcohol and stimulants of all sorts.

TO PREVENT SERIOUS ILLNESS

1—If you have a cold, feel bad, or are feverish, go to bed at once, cover up warmly and have the windows open; send for a physician and follow his instructions.

2—Do not take any so-called cures. There is no specific cure for this disease.

3—If you can not get a doctor, remain in bed, eat a simple diet, take plenty of fluids, such as water, fruit juices, milk bouillon, hot soups, at frequent intervals. Use a mild cathartic, if constipated.

4—Remember the most important measure of preventing pneumonia or other serious complication is to remain in bed until all symptoms have disappeared, and then, under the physician's advice, to return very gradually to your usual activities, being sure to rest before you get tired.

HENRY A. CHRISTIAN,
THEODORE B. APPEL,
J. P. LEAKE,
H. F. VAUGHAN,
R. C. WILLIAMS,
HAVEN EMERSON

[1] Report of the Committee on Preventative Measures of the Public Health Service.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

MOUNTING AMPHIBIA BY PARAFFIN INFILTRATION

CERTAIN difficulties seem to be inevitable in following the procedure for mounting Amphibia by paraffin infiltration as set forth by Noble and Jaeckle in The American Museum Novitates No. 233. A few changes have been found to give better results.

The terpineol, which is used as a clearing agent, has a tendency to cause the abdominal walls of most salamanders to collapse, and to harden the tissue so that it is almost impossible to renew the plumpness of the animal by a later injection of warm paraffin. Melted paraffin may be injected, however, before the animal is put in the terpineol, and the lifelike form will be maintained throughout the remainder of the procedure. In some of the smaller salamanders it is not necessary to repeat the injection after the paraffin bath.

Not only does this early injection of paraffin preserve the shape of the animal, but it shortens the length of the time required for the paraffin bath. The injected paraffin melts and passes into the viscera, so that all the paraffin which infiltrates the animal does not have to pass through the skin. This is important as the brittleness of the final mount seems to be proportional to the length of the time the animal is in the hot paraffin.

With some of the small salamanders, like the red-backed (*P. cinereus erythronotus*) and the two-liner (*E. bislineatus*), good results have been obtained by omitting the terpineol. The small animals clear quickly in xylol, and the week in terpineol which Noble suggests is eliminated. Of course absolute alcohol must be used in dehydrating if the terpineol is omitted.

Noble and Jaeckle state that in mounting the red elf, (the land stage of *T. viridescens*) tinted paraffin may be used. But they give no definite statement as to how this is done. All attempts to find tinted paraffin which would both keep its original color when heated and pass through the tissues of the animal easily have been of no avail in this laboratory. This particular animal may be colored very nicely by staining in eosin. In place of the 90 per cent. alcohol for the final dehydration use a saturated solution of eosin in 90 per cent. alcohol. The best results were obtained by staining overnight. It seems best to over-stain a bit because the finished mount is slightly duller than when taken out of the stain.

RALPH G. CLAUSEN

UNION COLLEGE

SPECIAL ARTICLES

THE GROWTH OF HOOKWORM LARVAE ON PURE CULTURES OF BACTERIA[1]

THE exact food that can be utilized by hookworm larvae in developing to the infective stage has never been determined. In his monograph on the free-living stages of the hookworm,[2] Looss makes the statement, "The normal food of the Ancylostoma larvae consists of the finest solid constituents of the feces, perhaps also of certain substances contained in them in solution." He further observes that "bacteria have not a sufficient nutritive value for the larvae." Other opinions as to the food of hookworm larvae have been very indefinite, such as "the fine organic detritus of feces," and so on. In fact, all observations have been made upon growth in fecal cultures under conditions where the factors are so numerous that it would be practically impossible to determine with certainty which substances were necessary for growth. In the present study, ova of the dog hookworm, *Ancylostoma caninum*, have been obtained free from feces and sterilized. These sterile ova have been inoculated onto agar cultures of various bacteria, and the larvae have hatched normally and grown to the infective stage with bacteria as their sole source of food.

The method employed for freeing the ova from the feces consists in thoroughly mixing up about 25 grams of freshly passed feces from a heavily infested dog in 500 cc of water. The mixture is then washed through a series of copper-wire sieves ranging up to a mesh of 100 wires to the inch. The larger particles in the feces are caught in the sieves but the ova readily pass through with the filtrate. This filtrate is allowed to stand in a large sedimenting cone for about an hour while the ova and heavy debris settle to the bottom. The supernatant fluid is then poured off; the sediment is transferred to a 50 cc centrifuge tube and repeatedly washed with water, the solid matter being thrown to the bottom each time by centrifuging at a speed of 1,000 revolutions per minute. After the supernatant fluid from the washing has become practically clear, saturated salt solution is poured into the tube and the contents are again centrifuged at the same speed. This time the ova come to the surface and may be collected by removing the surface film with the open end of a piece of large glass tubing.

[1] From the Department of Helminthology, School of Hygiene and Public Health, the Johns Hopkins University. The work was aided by a grant from the International Health Division of the Rockefeller Foundation and was carried out under the direction of Dr. W. W. Cort.

[2] A. Looss, 1911, "The Anatomy and Life-history of *Anchylostoma duodenale* Dub." Part II, "The Development in the Free State." Ministry of Education, Egypt, *Records of the School of Medicine*, 4: 163–613.

If the material is centrifuged four or five times, a majority of the ova present can be recovered. If much solid material comes to the surface with the ova, it may be necessary to refloat the ova in saturated salt solution a second or even a third time in order to get rid of the foreign material. This method is tedious and time-consuming, but if the feces of a *heavily* infested dog are used, large quantities of ova can be obtained almost entirely free from fecal material.

Ova collected by this method can be sterilized by treatment with a 5 per cent. antiformin solution in 10 per cent. formalin. From 10 to 50 per cent. of the ova remain viable after this treatment. The ova are washed several times with sterile distilled water and are then ready for inoculation onto the agar cultures. During the process of sterilizing and washing, the ova are best kept in a sterile 50 cc centrifuge tube closed with a cotton plug.

Cultures were made up in 250 cc Erlenmeyer flasks stoppered with cotton plugs, and consisted of 20 cc of ordinary bacteriological agar which had been diluted with three parts of water. The flasks were autoclaved and inoculated with bacteria twenty-four hours before the ova were introduced. Since at ordinary room temperature the ova do not hatch for an additional thirty-six hours, there was a heavy growth of bacteria in the cultures by the time the larvae were ready to begin feeding. The sterile ova were introduced into the flasks in 1 cc portions of an aqueous suspension, several thousand ova usually being put in each flask. In every experiment, 1 cc portions of this suspension were also inoculated into control broth cultures both before and after the inoculation of the experimental flasks. In this way the sterility of the suspension of ova could be checked. In addition, at the end of each experiment, in order to detect any possible contamination during the process of inoculating the flasks, subcultures in broth were made from the growths in the experimental flasks and after twenty-four hours examined by a Gram stain. When proper precautions were observed, only occasional contaminations occurred, and these flasks were discarded from the experiment.

In the experiments so far carried out larvae have grown to the infective stage in the normal period of about seven days on pure cultures of *Bacillus coli, B. subtilis, B. prodigiosus, B. lactis aerogenes, Staphylococcus aureus, Spirillum metchnikovi, S. rubrum* and *Micrococcus citreus.* Ova which were put on plain agar without bacteria hatched normally and lived for as long as ten days, but did not grow. If bacteria were then introduced into the flasks, the larvae grew to the infective stage. These experiments demonstrate that hookworm larvae in growing to the infective stage are able to utilize bacteria as their sole source of food.

Not all bacteria are suitable food for hookworm larvae, since they failed to grow on cultures of *Bacillus pyocyaneus* and *Sarcina lutea,* and growth was very much retarded on cultures of *B. cereus* and *B. megatherium.* Larvae, however, grew normally on a mixed culture of *Bacillus cereus* and *B. coli.* In all experiments quantitative methods were employed for counting the number of ova which were introduced into each flask and the number of larvae which developed.

The recovery of hookworm ova free from fecal material according to the procedure outlined above can be applied to obtain material not only for experiments on the food of the larvae but also for exact studies of the factors influencing their development. Almost all observations on the biology of the free-living stages of the hookworm have been made upon eggs and larvae in fecal cultures. Studies of the eggs and larvae free from feces in a controlled environment will make possible more definite knowledge concerning the influence of the various factors upon their development.

The conclusions drawn from the experiments in this report do not exclude the possibility that other substances than bacteria may serve as food for hookworm larvae. In fact, it is quite probable that other organic material may contribute to their nourishment. Various substances are being tested in this respect. But the experiments do demonstrate that certain bacteria may alone furnish adequate food for the growth of hookworm larvae to the infective stage.

OLIVER R. MCCOY

THE EXCITATION OF LUMINESCENCE BY THE AGITATION OF MERCURY IN GLASS AND TRANSPARENT FUSED SILICA TUBES AND VESSELS

IT is well known that when an exhausted glass tube containing a small quantity of mercury (leaving a partial vacuum, which must not contain even a trace of moisture) is held horizontally and given a reciprocating motion, static electricity is generated by the contact of the mercury against the glass, and the electrical discharges through the residual gas produce light. This is one of the most direct methods of producing electrical light by the expenditure of mechanical energy. As explained by Professor Elihu Thomson in an exceptionally valuable contribution,[1] "the electrification of the glass, by the running of the mercury over the surface, would, in neutralizing itself, together with the charge which the mercury acquired, illuminate the interior of the tube in much the same way that the Geissler tube is illuminated by the passage of an electric discharge."

Tubes of this kind have sometimes been designated as "mercurial phosphorus" and "Geissler's shaking

[1] "The Nature of Tribo-electricity, or Electricity of Friction, and Other Kindred Matters," *General Electric Review,* 25: 418–421, 1922.

tubes." A form that can also be utilized in demonstrating other phenomena has been described and illustrated by Professor Charles T. Knipp.[2]

The history of these tubes—which had their inception in 1675, when Jean Piquard, a celebrated French astronomer and scientist, noticed that a pale flickering light was playing in the Torricellian vacuum above the surface of the mercury column of a barometer which he was carrying through a dark passageway in the Royal Observatory of Paris—is given by W. S. Andrews[3] in a highly interesting paper. In the same contribution he describes his important researches on improved construction of these tubes and the phenomena exhibited, when he tested neon and various luminous substances in them. He states:

> About ten years ago (that is, about 1906) the writer made up some vacuum tubes specially designed to cause considerable mercurial friction when shaken and these tubes emitted quite an appreciable amount of light. These experiments were recently (1916) repeated, the tubes being filled with neon at a pressure of about fifteen mm. and, owing to the high sensitivity of this gas to electrical excitation, the amount of light emitted on shaking them was greatly augmented and it assumed the bright red glow that is the characteristic color of an electric discharge through this gas.
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> When an air vacuum is used and the exhaustion is carried to a very low pressure, say 0.001 of a mm (1 micron) or lower, the tube will glow with a pale blue light that probably shows a pure mercury spectrum, but this glow may be intensified and changed to almost any color by putting into the tube, before it is exhausted, some suitable fluorescent substance, such as zinc sulphide.
>
> This compound, under different methods of preparation, can be made to fluoresce in a variety of different colors, such as blue, green and various shades of yellow. The writer, by these means, has made "Shaker" tubes, that exhibit many different colors of light.

I correspond with Mr. Andrews, and the information relative to his tubes that he kindly imparted to me and which I give herein is published with his very kind permission.

In one of his letters he states:

> Tubes containing air, at a pressure of about 1 mm or less, show a whitish luminescence, and all gases, at suitable low pressures, are similarly excited. The presence of a fluorescent substance, such as willemite, in fine powder, introduced into one of these tubes, intensifies the luminescence, and gives it, in the case of willemite, its characteristic fine green color. If willemite is used, in a tube containing neon, at a very low pressure, the luminescence occurs in streaks or clouds of green and red, intermingled, which present a very beautiful appearance.

[2] "A Simple Demonstration Tube, for Exhibiting the Mercury Hammer, Glow by Mercury Friction and the Vaporization of Mercury at Reduced Pressure," *School Science and Mathematics*, 17: 442–3, 1917.

[3] "The First Electrically Lighted Vacuum Tube," *General Electric Review*, 19: 414, 1916.

The preparation of his synthetic fluorescent willemite is described in another paper.[4] He kindly informed me that in addition to the tubes described in his paper and letter, quoted above, he designed and constructed a large number of different sizes and various shapes, some with and others without an inner tube, such as the standard "shaking tubes" contain, and he found those with an inner tube, containing a number of constrictions and enlargements, to emit the most light. Also, that the enlargements on the inner tube must be located at the proper distance from the wall of the outer tube to obtain the best results. Moreover, the inner tube must be anchored at both ends to the outer tube to prevent its breaking in operation and, especially, in transportation, as the inner tube is subjected to considerable mechanical stress at the point of attachment, if only anchored at one end, and, consequently, sometimes is fractured at that junction.

In one variety the inner tube, instead of being open to the atmosphere at one end, as is the usual practice, was exhausted and then filled with neon at about 10 mm pressure; the outer tube contained a small quantity of mercury only and a partial vacuum. The neon in the inner tube was excited by induction through the glass wall of the inner tube by the electricity produced in the tube, when operated in the regular manner. The result was that when the tube was in operation there was produced a combination of red light from the neon in the inner tube, and pale blue light, from the mercury vapor in the space between inner and outer tubes, in streaks and flashes, and the effect was very pretty. In making tubes of this kind it is essential that the walls of the inner tube be made thin since otherwise the brilliance of the discharge is greatly reduced. Of course, hydrogen, helium, carbon-dioxide or any other gas at a suitable low pressure, or various fluorescent liquids, could be used in the inner tube instead of neon. A small quantity of some luminous substance, in powdered form, could also be placed therein. In this case the gas used in connection with the fluorescent compound would have to be at a very low pressure. Moreover, the outer tube, instead of containing mercury only, could contain, in addition to the mercury, various gases at suitable low pressures and also luminous compounds in powdered form.

Mr. Andrews experimented with neon at pressures from 5 mm to 20 mm, but he believes that the best results were obtained when the pressure was from 10 to 15 mm. He found that at a pressure less than 10 mm the red color of the neon glow became weaker,

[4] "Notes on the Preparation of Some Fluorescent and Phosphorescent Compounds," *The American Mineralogist*, 7: 19–23, 1922.

and at over 15 mm it also seemed to lose color. He found that the most important thing to attend to in making these tubes was the careful exclusion of water vapor by heating the tube under exhaustion with a gas flame.

A small speck of a radium salt in a shaking tube containing neon increased the ionization of the gas and made it glow more brightly.

Upon rubbing one of his shaking tubes with a warm dry piece of silk a faint glow was discernible, but the intensity was very low compared with the light emitted by the interior excitation, by mercury against the glass.

Dr. W. A. Darrah investigated the operation of one of these tubes containing neon.

In a letter to me (published with his very kind permission) he stated:

> I was particularly interested in noting that, on agitating the tube slowly, the glow always comes from the portion of glass wall and mercury which has been separated, and never from the parts which are approaching. This, of course, is what you would expect, from the ordinary laws of frictional electricity, except that I should have anticipated that the charge would have been distributed widely over the metallic surface.

Mr. Andrews and the writer have verified Dr. Darrah's discovery, which is a valuable addition to the information contained in the explanation given by Professor Thomson and quoted above.

Transparent fused silica can also be used instead of glass in the construction of single and double shaking tubes.

Production of Light by Rotating Vessels of Glass or Transparent Fused Silica

Mr. Henry Schroeder, in his "History of the Electric Light,"[5] describes Otto von Guericke's electric machine (1650) in which a ball of sulphur was rotated, electricity being generated when it rubbed against the hand. There is a charming illustration on page 2 of his monograph which depicts, in addition to the artistically constructed electrical apparatus, ladies and gentlemen attired in the quaint costumes of that period. Francis Hawksbee's (1709) with its hollow glass globe which could be exhausted is likewise described. The exhausted globe when rotated at high speed and rubbed by hand would produce a glowing light and this "electric light," as it was called, created great excitement when it was shown before the Royal Society in London.

This suggested to me the production of light by the rotation of glass or transparent fused silica vessels containing mercury and a partial vacuum, or mercury and various gases and luminous substances.

On February 6, 1925, I communicated my ideas to Mr. Andrews, suggesting the construction of several shapes of vessels, including spherical and tubular, and, in compliance with my request, he very kindly undertook such research.

He also made some vessels, indented, corrugated, etc., in accordance with his own ideas for modifying their shape to increase the intensity of light produced.

He attached Edison electric incandescent lamp bases to the vessels and a keyless Edison incandescent lamp socket to the horizontal shaft of a variable speed electric motor, the center line of socket being aligned with the center line of shaft. The different vessels could then be screwed in socket on shaft and rotated at various speeds.

He found that the best speed to use for the small vessels tested, when they contained a small quantity of mercury and neon at 10 to 15 mm pressure, was 700 to 800 r. p. m. for a plain smooth spherical vessel and 400 to 500 r. p. m. for a corrugated one, with the corrugations parallel to the horizontal axis of rotation. The neon in the plain vessel then emitted a bright red light, and the effect produced in the corrugated one was much brighter and exquisite.

Naturally, a lower speed of rotation must be used for the corrugated vessel, to avoid its destruction by the violent agitation of the mercury contained therein. However, this danger could probably be eliminated if thicker glass was used in its construction, thus permitting higher speed of rotation and consequently increase in intensity of light emitted by neon, etc. He did not have the opportunity to test luminous substances in such vessels.

I believe that further researches on the size, shape and contents of single vessels should be made; and on use of glass of various compositions and also of glass containing various impurities for the construction of single and double vessels. Variation of the size and shape of both inner and outer vessels, some inner vessels of similar shape and some dissimilar to outer vessels, should be tried; the optimum spacing, between inner and outer vessel, should be determined; the thin inner vessel should be anchored at both ends to the outer vessel, to insure mechanical strength in operation and transportation; filling the inner vessel with different gases should be tried, and also placing therein a small quantity of luminous substances in powdered form and exciting these by induction, in the manner used for the shaking tube constructed by Mr. Andrews and described earlier in this paper; various fluorescent liquids could be used in the inner vessel, but *not* in contact with the mercury in the space between the vessels, because of the deleterious effect of the presence of moisture. However, various

[5] Smithsonian Miscellaneous Collections, 76: No. 2, Pub. 2717, published by the Smithsonian Institution, Washington, D. C., August 15, 1923.

gases and luminous compounds, in powdered form, can be used there.

By using transparent fused silica vessels for such experiments and a spectrograph with quartz prism and lenses, all the visible and invisible radiations produced in the vessels, when they contain mercury and various gases and luminous substances, could be investigated. The effect of a minute quantity of a radio-active compound in increasing the intensity of the luminescence (discovered by Mr. Andrews and previously referred to) should also be thoroughly studied, in all types of vessels and all varieties of contents.

Tests of this kind would be of great scientific interest, and, eventually, possibly lead to results of practical value.

W. L. LEMCKE

FRANKLIN, PA.

THE INORGANIC CONSTITUENTS OF MILK

RECENT investigations have shown the importance of even minute traces of certain inorganic constituents in the normal growth of plants. Manganese, boron and zinc appear to be essential, and copper may also have an important function. Investigations of the elements essential for animal growth are beset with far greater difficulties, since we rely on natural foodstuffs for the main bulk of experimental rations, and these will bear considerable quantities of the lesser recognized elements as impurities.

If one excepts its low iron content, whole milk has until recently been held to provide an "adequate" diet for the growth of the young of the same species, and it is permissible to assume that a study of the inorganic constituents of milk will give some indication of the elements essential to animal growth. No data are available which give full analyses of the inorganic constituents of milk, either qualitative or quantitative.

During the past year, samples of cow's milk have been obtained from various parts of the United States and of Great Britain, and qualitative examinations have been made of the ash constituents of these samples by spectrographic analysis. The samples were milked straight into glass bottles. They were evaporated to dryness either in silica or in platinum dishes and ashed at low temperature in an electric muffle furnace. Spectrograms of the ash were prepared with the aid of a quartz spectrograph by placing the ash in an arc between two pure graphite electrodes. Examinations of the spectrograms were made between λ 2,400 and λ 4,600 angstroms.

Samples from the following localities were examined: *United States,* New York State, New Jersey, Wisconsin, Michigan, Missouri and California; *Great Britain,* Somersetshire, Derbyshire and Aberdeenshire. The spectrograms obtained from all these samples were qualitatively identical, and from them it has been possible to determine the elements normally occurring in milk.[1] The results may be summarized as follows:

Elements previously identified, and confirmed by spectrographic analysis		Elements not previously identified but now found to be present
Large quantities	Traces	Traces
Calcium	Iron	Silicon
Magnesium	Copper	Boron
Potassium	Zinc	Titanium
Sodium	Aluminum	Vanadium
Phosphorus	Manganese	Rubidium[3]
(Chlorine)[2]	(Iodine)[2]	Lithium
		Strontium

It should be noted that the newly recognized elements are present in small *but definite traces.* Whether they are significant in nutrition remains to be determined. Two of the samples examined deserve special mention. With one sample the spectrogram indicated more than the usual amounts of copper. On reference to the records this was found to be a sample of dried milk. With the second sample the analysis indicated more than the usual amounts of zinc. On reference to the records, it was found that this sample had been obtained from cows pasturing in the neighborhood of the zinc smelters at Franklin, N. J. Such results give ground for placing considerable reliance on the spectrographic analysis, while the occurrence of zinc in more than usual quantity in the milk from the neighborhood of zinc refineries indicates that in some cases the quantity of an element may be directly influenced by its concentration in the soil.

In conclusion, the method of spectrographic analysis as applied to biological materials appears from this work to warrant more attention. The method may well be applied to biological material both qualitatively and semi-quantitatively.

NORMAN C. WRIGHT

THE HANNAH DAIRY RESEARCH INSTITUTE, SCOTLAND

JACOB PAPISH

DEPARTMENT OF CHEMISTRY, CORNELL UNIVERSITY

[1] See, however, footnote 3.

[2] This element can not be confirmed by the spectrographic method employed, but its presence has been adequately confirmed by other methods.

[3] In a sample of milk ashes recently examined by one of us (J. P.) the presence of rubidium could not be established with certainty.